Library of Wonders

WONDERS OF WATER

Llewelyn Jenkins
January 8th 1880

FIG. 52.—WATER-CARRIERS OF DIFFERENT COUNTRIES.

WONDERS OF WATER.

FROM THE FRENCH OF

GASTON TISSANDIER.

THE ENGLISH REVISED BY

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WONDERS OF WATER.

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BOOK I.

THE OCEAN.

CHAPTER I.

"The contemplative mariner, as in mid-ocean he looked down upon its gentle bosom, continued to experience sentiments akin to those which fill the mind of the devout astronomer when in the stillness of the night he looks out upon the stars and wonders."—MAURY.

THERE is no more imposing spectacle than that afforded by the sea. In watching the ceaseless motion of the waves, which roll gently upon the shore, and the restless undulation of the billows, which chase one another with a plaintive murmur, we can well understand how the inventive imagination of man should have personified this mass of inert matter; and we sympathise with Schleiden, when, in his poetic language, he has compared the motion of the waves to a gentle respiration. The observer looks towards the distant horizon; and the liquid circle with which he is surrounded often melts so insensibly into the vapoury distance, that sea and sky become united and blend into one.

Extent.

"On the globe," says Michelet, "ocean is the rule, earth the exception." It is by no means easy to estimate exactly the superficial extent of the sea: the slow movements of the ground, which rises and falls; the waves, which are incessantly abrading the rocky shores; the coral banks which daily increase in the bosom of the sea, and rise to its surface, constantly modify the line of coast, and produce a change in the relative proportion of land to water. It is, however, clearly ascertained that the sea covers at least two-thirds of the surface of the globe. The sea is very unequally distributed over the globe, the southern hemisphere being far more abundantly provided with water than the northern. Thus the terrestrial globe may be roughly divided into two halves, one being looked upon as the region of the sea, and the other as that of the dry land.

Depth.

"We perceive as many inequalities in the depth of the sea, as on the surface of the earth."—BUFFON.

During many centuries the most confused ideas prevailed on the subject of the depth of the sea, and the early nations beheld in the vast unknown oceans an impassable barrier—a gulf, without bottom and without shore.

The operation of sounding the sea is attended with great difficulties. The line is continually drawn aside by submarine currents, so that even when the lead has reached the bottom the line continues to run out. Some ingenious machines have, however, been invented capable of overcoming these difficulties, and accurate measurements have been made by several competent navigators. Brooke's line is that which has given the most satisfactory results; after having touched the bottom of the sea, it brings back

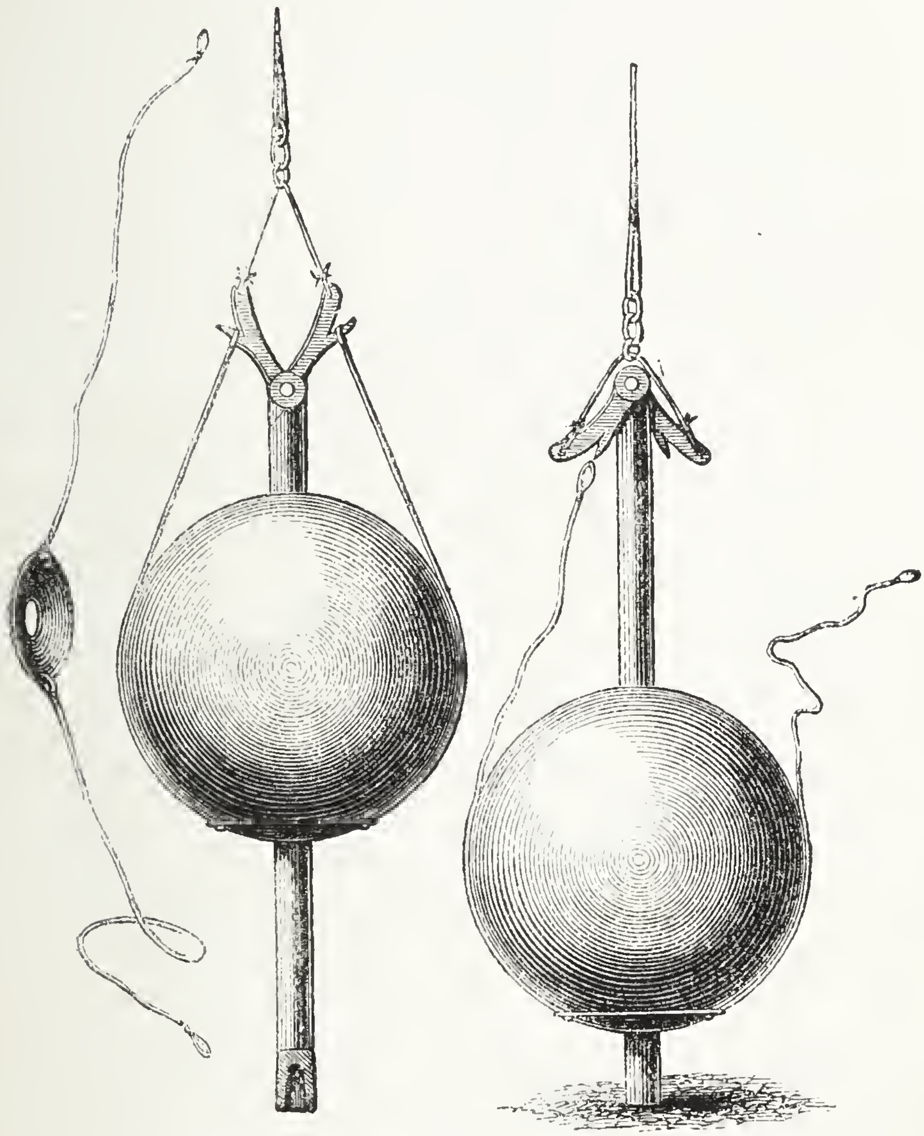

FIG. I.—BROOKE'S INVENTION FOR DEEP-SEA SOUNDING.

specimens of the greatest value to science.* A ball of 70lbs. weight is pierced with a hole, through which passes

* It is in the plateau of the Atlantic that Brooke's invention brought the first specimens from the bottom of the sea. Though in appearance

a loose iron rod, terminated at its lower end by a cylindrical cavity. As soon as the rod reaches the bottom the ball is detached by a simple contrivance, while the rod is easily brought up again to the surface. Fig. 1 shows on the left the line before it has reached the bottom, and on the right the ball when it has been detached and the rod is about to be raised. The mean depth of the ocean, according to Humboldt, is nearly two miles; according to Young, the mean depth of the Atlantic Ocean is about half a mile, and that of the Pacific about two miles and a half. Not far from the shores of the United States, Lieutenant Walsh paid out a vertical line six miles long. This fact is at variance with some calculations of Laplace, who, founding his opinion on the influence exercised upon our planet by the sun and moon, considers it to be impossible for the depth of the sea to exceed five miles.

It has, however, been proved by unquestionable evidence that in some localities the ocean attains immense depths, which, occasionally surpass the height of some of the loftiest mountains of India and America. Sometimes, also, the ocean covers the earth with only a thin layer of water. At the mouth of the Po the sea's depth does not much exceed 50 yards, while the bottom of the Baltic is never more than 220 yards deep. The dome of the Pantheon at Paris would rise above the level of the Straits of Dover, and the shallowness of the Strait which separates France from

earthy, the matter raised seemed to be composed of a number of microscopic shells in perfect preservation, belonging to the group of the Foraminiferæ—animal forms of a low type. In the Indian Ocean, spiculæ of sponge have been found at a depth of upwards of two miles. It is evident therefore that in the depths of the sea are to be found bodies of various kinds.

Great Britain encourages the hope that the two countries may be, ere long, united by a submarine tunnel. It will not be long before science gives us still more intimate and accurate information on the subject of the depth of the ocean; and Maury, the celebrated director of the Observatory of Washington, has already constructed an admirable orographic chart of the basin of the Atlantic. On this chart the darkest shading represents a depth of upwards of four miles, and the lighter shades show the gradually decreasing depth.

A vertical section of the basin of the Atlantic, shows us how hilly and uneven is the ground which lies beneath the waste of waters.

If the sea were to retreat from this vast trench, leaving bare the terrestrial surface, what relics would not be disclosed amid the ripples of the shallow water! "There," says Maury, "would be brought to light that array of dead men's skulls, great anchors, heaps of pearl, which in the poet's eye lie scattered at the bottom of the sea, making it hideous with sights of ugly death." The bottom of the sea is formed of mountains and of valleys, of table-lands, ravines, and hills. Our continents are, in point of fact, nothing more than the unimmersed summits of these mountains. The waters, in obedience to the law of gravity, collect by reason of their mobility in large basins, and spread themselves over the lower portions of the terrestrial surface. If the surface of the globe, instead of being rugged and uneven, were as smooth and uniform as a ball of ivory, the sea would entirely cover it with a layer of about 219 yards in thickness. The area of water which covers to a large extent the surface of the globe is considerable, relatively to the area of the land; but the volume of the water is very small, when compared with the whole mass of our planet. If we divide the entire globe into 1,786 portions of equal weight, one of those portions will give the total weight of the waters of the sea.

Colour.

Sea water, if enclosed in a bottle, appears colourless ; but seen from the shore it is generally of a beautiful green, and when viewed from a greater distance it assumes an azure hue. The Polar Seas are, according to Scoresby, of an ultramarine tint; the Mediterranean is sky blue (Costaz); and the poets themselves would find it difficult to describe the exquisite effects of colour in the Bay of Naples, when the rays of the sun cause the waves to sparkle with a thousand fires, like those of the sapphire and the emerald. The Black Sea owes its name to its frequent tempests ; the White Sea, to its masses of floating ice.

The natural hue of the waters is frequently modified by the presence of animal and vegetable life. Thus the Polar Seas are at times streaked with millions of medusæ, the yellow shade of which, in combination with the blue of the water, produces green. Certain portions of the sea become at times as white as milk, while in other cases they present the hue of blood. These singular phenomena, which were described by ancient authors, are due to the myriads of algæ which float upon the waves, and modify their colour. The Red Sea has frequently presented the appearance of a sea of blood. In July, 1843, for two days the natural colour of the waves disappeared beneath a layer of carmine. Analogous facts have come at various times under the observation of mariners in many places. The sailors of the ship *La Crede* saw, in 1845, the waters of the

Atlantic covered with a purple mantle, which extended over a surface of six square miles. These accidental colourations were for many centuries a source of terror to the superstitious; but men have now ceased to behold in the fortuitous apparition of microscopic algæ floating on the surface of the water, signs of the anger of Heaven, or presages of coming calamities.

The black mud and the yellow sand, which in some places carpet the bottom of the sea, modify the apparent colour of transparent and shallow water, especially when the sea is viewed from an elevated position. The state of the sky is also a cause of variation; and the sea may be looked upon as a vast mirror, changing its aspect according to the images which are reflected from it. Black and sombre when thick clouds hide the rays of the sun, the sea attires itself with a thousand sparkling fires when the vault of the firmament is transparent and azure.

It is probable, however, that water has a colour of its own, which appears to be either blue or green. In this respect it resembles the air, colourless when seen through a limited thickness, but blue when the eye penetrates its depths. Could we descend into the ocean, we should see the emerald shades disappear, the light of day would fade gradually, we would penetrate into gloomy twilight, and at length become buried beneath thick darkness.

During the night the sea is often radiant with a strange lustre. The white foam is replaced by fiery bands; each wave in rolling over shines with a mysterious brilliancy. These phenomena are the effect of an infinitude of animalculæ, which illumine the undulations of the waves while the stars are lighting up the expanse of heaven. Nothing is more striking than this spectacle, which is manifested under the most varied aspects on the surface of the Southern Ocean. Mariners tell of enormous balls of fire which appear to roll over the waves, of moving cones of light, of garlands, of glittering serpents, and of shining clouds, which wander over the waves in the midst of the darkness. The phenomenon is here complicated by some optical effects, which, with the nocturnal movements of phosphorescent animals, explains all these marvels. The sea is not a vast liquid desert; there is not a single drop of water inaccessible to the manifestations of life; and in the ocean the prodigious fecundity of nature finds its highest development.

Temperature.

The ocean is divided into three immense thermic basins, the two first being situated at the poles, while the third, lying midway between the two others, is situated near the equator. The temperature of the sea, heated by the action of the solar rays under the equator, is tolerably high at the surface; but at a depth of 1,200 fathoms it sinks down to 4_0.* The further we go from the equator, so much nearer to the surface do we find this temperature of 4°. At a certain distance from the equator there appears to exist all round the globe a zone in which the temperature of the ocean is constant and uniform in all depths. As we recede from this limit, and approach either of the poles, we find a lowering of the level of uniform temperature; and at the latitude of 70° this level is at a depth of 750 fathoms. Round the poles the surface of the water is frozen, and formidable icebergs float over the polar sea during the whole year. (Fig. 2.)

* Throughout this volume the temperatures are expressed in the centigrade scale.

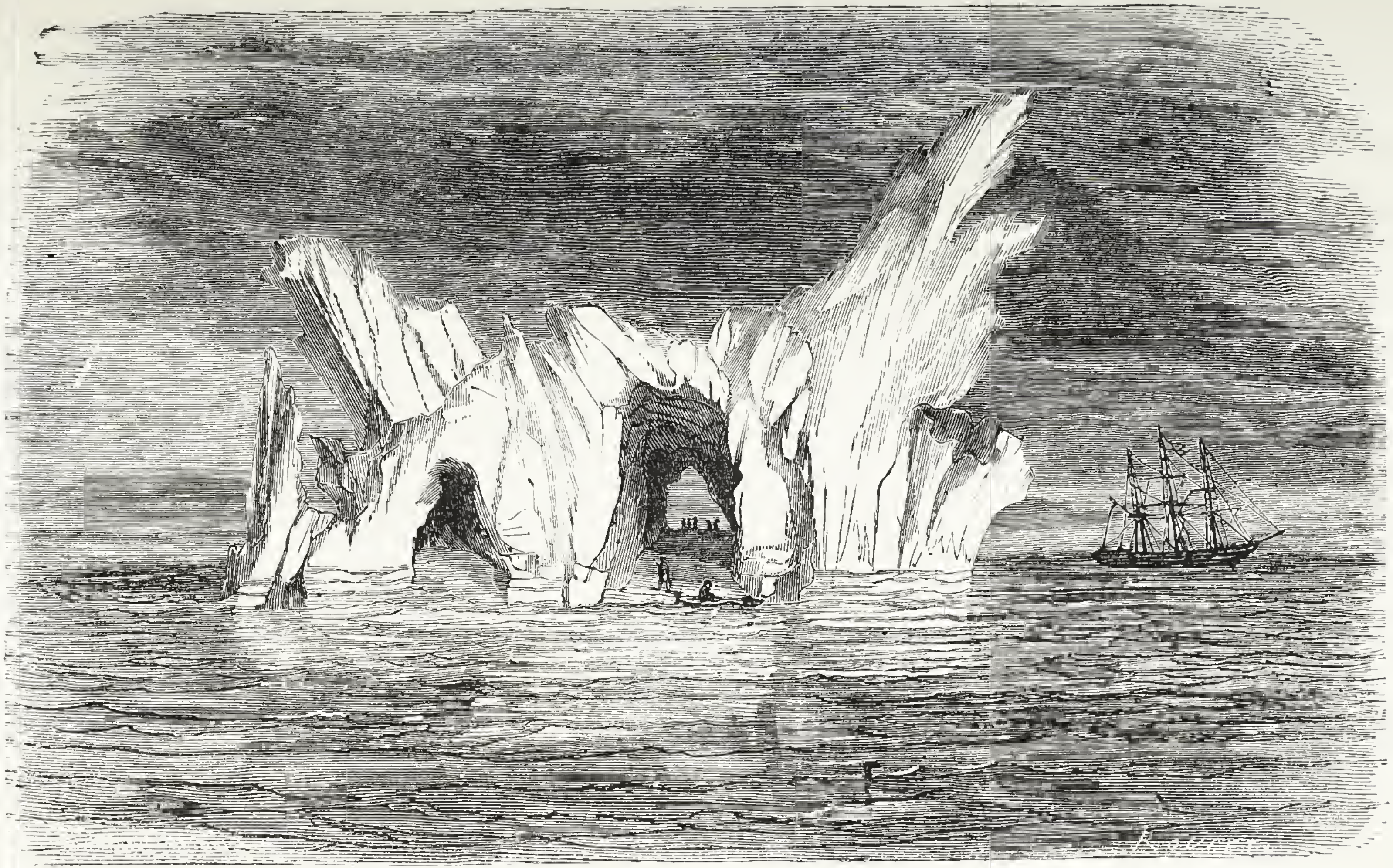

FIG. 2.—ICEBERGS.

Scenes really magical break the monotony of these Arctic regions, where a whole architecture of ice presents itself to the dazzled gaze of the traveller. Light gusts of wind appear to impart a gentle motion to the transparent pinnacles and the floating porticoes, when, lo! the whole disappears as if beneath an enchanter's wand, to reappear under new forms. And though but little of vegetation bears witness to the vitality of the earth, or charms the eye, the sky produces pictures of the most thrilling beauty. Yet at what cost does the voyager behold all this strange loveliness? It is necessary in order to see it that he should endure the long nights of the Arctic winter, and that he should live in the midst of frightful solitudes, hidden under a pall of thick darkness; while the doleful sounds made by the icebergs, as they dash against one another and become broken, suggest to his mind unpleasant presentiments. Terrible indeed it is when the sun, from which we derive both heat and life, is no longer to be seen above the horizon.

CHAPTER II.

THE MOTION OF THE SEA—SUPERFICIAL AGITATION.

THE water of the sea is in ceaseless agitation; its surface obeys the impulses of the wind, and its waves strike continuously against the rocky shore. Looking upon this incessant struggle between land and water, this irreconcilable strife betwixt liquid and solid, it might seem as though inert matter, jealous of organised being, strove to imitate the activity of life. Whilst gazing upon the waves which dash against the cliffs, we feel inclined to question whether this heaving mass be really only an inorganic element; we feel tempted to believe that a breath of life causes this movement in these never-resting waves, and animates a being which has its moments of anger and of calm, and of which the voice, now sweet and harmonious, can anon become menacing as the cries that escape from an oppressed bosom.

The waves of the sea, majestic and tranquil, are at times subject to the most terrible convulsions. When violently agitated by the wind, the waves pursue one another; they rise and fall in torrents of foam, and during great storms mariners have seen waves attain a height of thirty-six feet. Whilst dashing against the rocks of the shore, they move with a startling rapidity, and acquire an irresistible force. These convulsions of the sea are never felt at a depth of more than 660 feet, and nature has thus provided for the safety of the myriads of living creatures that people the ocean, in permitting them always to find at a certain distance beneath the level of the waters a calm and quiet retreat.

Gigantic waves are to be met with in almost all seas. Near the coasts they give birth to breakers, which are a just object of dread to mariners, and at the mouths of rivers they produce what are called bores. The last phenomenon assumes enormous proportions on the American shores, where the largest fluvial arteries of the world are discharged into the sea. At the period of spring tides, nothing is more terrible than the struggle between the waves of the sea and the current of the Amazon. The whole breadth of the river is overrun by one tremendous wave, fourteen feet in height, causing a noise which is heard at a great distance. All obstacles are thrown down or destroyed, trees are uprooted or snapped in two, and everything swept away from the bank to a distance of 200 yards.

Certain agitations of the waves produce, in other parts, the not less formidable phenomena of whirlpools. Among the whirlpools of the sea, the most celebrated is the maelstrom. According to ancient tradition, this was a gulf perpetually roaring, always yawning to swallow up any ship which may venture too near its formidable jaws. It is right, however, to add that the dangers of the maelstrom have been grossly exaggerated. Some marine currents, undoubtedly dangerous to sailing vessels, have given rise to the fable, which modern seamen have entirely discredited.

The Tides.

"If the waters offer matter of wonderment to our sight, it is mainly in the spectacle of the ebb and flow of the sea."—PLINY.

The waves are the caprices of the sea. They vary according to localities, following the impetus of the wind, and are not governed by any force which is constant in its effects. But the sea is endowed with other and more regular movements. Our globe is isolated in the immensity of the universe, but it is not solitary. Ever subject to the influence of those bodies which people space, it yields to their attraction; it is *en rapport* with the skies! Just as the sunflower is said to look up to the sun, and to turn her face towards him, so, twice a day, the ocean swells her bosom towards the powerful attraction of the sun and the moon. The combined action of these two bodies draws daily round the globe the immense waves which rise to their utmost heights at the periods of new and full moon. During six months of the year, the highest tides occur in the day-time; and during the other six months, at night. At these periods the waves encroach upon the shore, and bathe those parts which are usually free from contact with the waters. The highest spring tides rise in the open sea through an altitude not exceeding three feet from high water to low water, but as the waves approach the seaboard of the continents, which appear to oppose barriers to their invasion, they increase considerably, and sometimes rise even through a height of sixty-five feet above the level of low-water. All seas are subject to this marvellous influence of the tides. Everywhere beneath the empire of the waves the ebb and flow depresses and elevates the liquid surface. Incessantly opposed and modified by the shape of the coasts, by headlands, by currents, by the force of the winds, the action of the tides is most felt in straits, and in gulfs; thus some of the highest tides are met with in the Gulf of St. Malo, in the English Channel. Their vertical height is fifty-six feet off the island of Ushant; forty-nine feet between Jersey and St. Malo. In America the tide rises from forty to sixty feet in the Bay of Fundy. In the polar regions, Franklin has ascertained that the tide never rises above twenty inches, and sometimes only three inches.

It has often been affirmed that the waters of the Mediterranean are not subject to the oscillations of the tide. This assertion has been disproved by observations which have been made at Toulon, at Venice, and at Algiers —in which places the existence of ebb and flow has been observed. In all seas of small extent, the tides have but slight, that is to say, but slight *perceptible* influence. This fact is very easily explained; when the tide is high in one part of the ocean, it is low at a distance of 90 degrees, and the liquid prominence is only formed at the expense of the depressed waters—in lakes of small extent this is impossible, and the presence of a tide cannot therefore be detected. These facts often presented as an objection to the Newtonian theory of tides, are rather a confirmation of the doctrine.

The tides purify and wash our shores, they cleanse and sweep over our ports; the currents which result from tides disencumber our roadsteads of the mud which loads them, and clear the mouths of rivers. We feel in the approach of the tide the salutary effects of a freshness pure and vivifying. The undulations of the ocean, those powerful pulsations of the water, are produced by bodies which are separated from our planet by thousands of miles, yet have the tides not less mathematical regularity than that which directs these planetary bodies themselves. At a fixed hour the formidable masses of water upraised by an invisible agency, rise and approach the shore. They advance, they precipitate themselves with a resistless power only to stop gently at a certain moment, without passing the boundary which nature has indicated. Is it not to the credit of the human race, to have become able to calculate the exact moment, in which the oscillations of the sea begin and end?

The Currents.

There exist in the sea immense currents, which may be regarded as veritable rivers in the bosom of ocean. Members of a great arterial system, they play a highly important part in the harmonies of the globe. They establish a kind of interchange between the extreme temperatures of different climates, transporting towards the poles the warmer water o the tropics, and carrying the cold water of the glacial region towards the torrid countries of the equator. Christopher Columbus was one of the first to record observations on the marine currents; he recognised, after his second voyage, that the waters of certain parts of the Atlantic followed the apparent motion of the stars. "The waters," says the great navigator, "march with the sky."

The physical geography of the ocean is a science which is still in its infancy; the initiative step in its development has been recently taken by Commander Maury, and it is only through his labours that the course taken by any of the marine currents has been accurately determined.

Between the tropics, in all seas, we meet with equatorial currents travelling from east to west; but the most powerful and best known of all currents is the Gulf Stream.

The Gulf Stream is a prolongation of the equatorial current of the Atlantic, of which the origin still remains in obscurity. This equatorial current, after having washed Western Africa, veers round, and proceeds across to America. At some distance from the coast one branch of the current becomes detached, descends towards the south, and forms the Brazilian current. The main artery goes northward, coasts along Guiana, receives into its bosom the waters of the Amazon and the Orinoco, and penetrates at last into the Gulf of Mexico.

When the equatorial current escapes from this gulf, it receives the name of the Gulf Stream. It passes through the Straits of Florida in a majestic current, upwards of thirty miles broad, 2,200 feet deep, with an average velocity of four miles per hour; and its waters are warm and salt, of an indigo blue, which contrasts with its green banks, formed by the waves of the sea.

Compressed between two liquid walls, the waters of the Gulf Stream form a moving body, which glides over the empire of the sea. It is a vast river in the midst of ocean. "In the severest droughts," says Maury, "it never fails, and in the mightiest floods it never overflows. Its banks and its bottom are of cold water. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississippi or the Amazon, and its volume more than a thousand times greater."

With the aid of the thermometer the navigator can follow this great liquid artery; the instrument, plunged alternately near its edges or in its centre, will indicate temperatures differing 15 degrees. Powerful and rapid, the Gulf Stream pursues its way in a northerly direction, following the shores of the United States as far as the banks of Newfoundland. It then has to sustain a terrible shock from a polar current, which drifts along enormous icebergs, absolute mountains of ice. The Gulf Stream, with its warm and rapid waters, dissolves the floating ice, the icebergs become broken, and earth, gravel, and even fragments of rock, which they carry along with them, are swallowed up by the sea. The infusoria and other animalculæ which swarm in the Gulf Stream, collect upon these fragments of stone. The rocks, earthy matter, debris of every description, are piled up together. They gradually rise, and will one day pass over the ocean level and form islands. It is in this way that the banks of Newfoundland have already been formed. But in this fierce contest the Gulf Stream is vanquished. It is broken by the impetuous shock, and becomes subdivided into several currents; one of these flows northward, melts the ice of Norway, and mitigates the rigours of the climate. It even possesses sufficient vigour to advance as far as Iceland, and casts upon the coasts of that island the trunks of trees, and fragments of wood, which it has borne from the shores of the New World. The Gulf Stream supplies the only fuel which the Icelanders, frozen as they are at the foot of a volcano, are able to obtain. The right arm of the Gulf Stream flows eastward, and directs its course to the British Islands, which it surrounds with what may be termed a mild and genial liquid girdle. It softens the climate of Scotland, and improves its vegetation; a portion of the current enters the English Channel, and enables the fig-tree to flourish in Brittany. Without this genial current, which dispenses so widely the blessings of a mild temperature, Scotland would have the climate of Siberia, which, situated beneath the same latitude, has, in winter, to endure cold of 20 degrees below zero. Without the same soft influence, the winters of Brittany would be no longer so mild as they are.

During the winter, landing on the shores of the United States is sometimes difficult and dangerous. On this coast the mariner is exposed to storms of snow and gales of cutting wind, which severely try his courage and experience. Masses of ice surround the ship, a freezing mist benumbs the crew, the rudder becomes fixed, and frozen, and its management is a hard and perilous task ; disaster seems imminent, but the Gulf Stream is at hand to bring help to the mariner in his need. If he makes haste to steer his vessel into the tepid waters of the stream, he will see, as if by enchantment, summer succeed to winter, and the melting ice fall gradually off. The sailor finds his energies recruited by the reviving warmth, and, thanks to the generous current, he will reach his destined port.

The Gulf Stream exercises a vast influence upon meteorology: violent gales and squalls frequently follow in its track. The waves of this mighty current are often agitated by tempests, excited by terrible cyclones. The waves are especially formidable when the wind blows in a direction contrary to that of the Gulf Stream, and it often happens that the atmospheric currents traverse for great distances along the course described by this body of warm water.

In the vast liquid triangle formed by the Azores, the Canaries, and the Cape de Verd Islands, in the centre of the great oceanic circuit of which the Gulf Stream forms a part, are to be found, in a tract of many thousand square miles, such a quantity of marine plants that the progress of ships is frequently obstructed. The companions of Columbus, alarmed at this obstacle, and astonished at the sight of so abundant a vegetation, imagined themselves to have reached the extreme limits of the navigable world.

This accumulation of algæ is also due to the marine currents; in fact, the Atlantic is an immense basin, in the midst of which the gulf weed constitutes the Sargassum sea. It can be shown by a simple experiment how nature can accomplish this phenomenon. Place some light substances, such as pieces of cork, in a basin full of water, give the water a circular motion, and the floating objects will immediately collect in the centre of the liquid surface. The Sargassum sea is not, however, a phenomenon peculiar to the Atlantic, as it is to be found more or less in all great oceans.

A warm current follows the shores of China and Japan, which the Japanese geographers have known for centuries, and it can be found marked on many ancient charts. In the southern seas, the currents are much less perfectly developed, and comparatively little is known with reference to them.

It is probable that the marine rivers are not mere isolated currents, but parts of a great network; the individual veins of one vast system of circulation. The existence of these systems is often indicated by tracing the history of corked bottles which have been carried by the currents Several of these little floating buoys left out at sea off the coast of Africa, have been found again, after many years, near the shores of Scotland. The cocos de mer of the Seychelles are carried along by marine currents, which, after having borne them for a voyage of four hundred leagues, deposit them in safety on the shores of Malabar. Here they take root, and thus live and grow far away from the country which gave them birth. The Hindoos believe that the ocean nourishes in its depths the marvellous trees which produce this enormous fruit.

The great current which flows from the eastern coast of South America, has drifted from Guiana and Brazil no less than thirteen species of plants as far as Congo. Certain other seeds, provided with a covering impervious to water, though tossed by the waves and rocked by the storm, retain their vitality after vast voyages. The fruits of the cocoa-nut tree, and the pods of the mimosa, are snatched from the soil of equatorial America by these rivers of the sea, which afterwards cast them upon the rocks of Scandinavia, where the want of heat prevents their development.

These marine currents render signal service to navigation; and, thanks to the facilities which they give, we can accomplish certain voyages much more rapidly than was possible before we understood their movements.

But the highest use of the marine currents is to equalise the temperatures of the globe, in which they act like the pipes of a mighty heating apparatus, conveying warm water from the torrid zone. They seem as if, to use Michelet's expression, they were desirous of offering "consolation to the frigid pole," by passing into it a stream of warmth and life to combat its icy coldness. A few examples may suffice to explain the influence of these marine currents in equalising the temperatures of the globe. New York is situated in nearly the same latitude as Lisbon, but the climate of the great American city is much less mild than that of the Portuguese capital, in which oranges grow. A map of the marine currents shows that a liquid artery, intensely cold because it comes from the pole, bathes and chills the shores of America. That branch of the Gulf Stream which skirts the coast of Norway, clothes the Norwegian fiords with a carpet of green, while the Baltic and the White Sea, situated beneath the same latitude, have a much colder climate. The tracing out of these currents, so long ignored, is one of the proudest conquests of science, a fruitful victory which offers to the thinker a vast field for study and meditation. It is a discovery invaluable to the navigator, who, when in the immensity of ocean, can now find tracks which can help to guide him through the wide expanse.

Duperrey, Berghaus, Petermann, and more recently Maury, have prepared admirable charts of the ocean. The velocities of those currents which furrow the fluid portion of the globe, are represented, with the direction of their course. The various temperatures are also indicated. The mariner, furnished with this atlas, is armed with new resources, which permit him to risk more hopefully the fortune which he confides to the uncertain waves.* The fisherman, also, has gained thereby much useful information, and can often find his way to the quarters favourable to his craft, by following the indications afforded by the temperature of the water. He must never, for instance, enter into the currents of warmer water if he wishes to invade the territories of the whale, for that huge animal only exists in cold regions. The torrid zone arrests his rambles like a wall of flame.

In the Indian and Pacific oceans, and, indeed, everywhere in the sea, liquid currents furrow the surface of the water; but the great circulation is not only superficial. Submarine currents traverse all parts of the sea, in the

* In order to travel by sea from New York to California, 160 days were formerly required. Now, owing principally to our acquaintance with the currents, the same trip occupies but 145 days.

bosom of which immense hidden arteries ramify in unknown directions.

In the middle of the Atlantic, Lieutenants Walsh and Lee, of the American Navy, having fastened to a fishing-line a block of wood charged with lead, dropped it into the sea to a depth of about half a mile. The apparatus was then left to the mercy of the waves, after having been provided with a float, in order to prevent its sinking to the bottom. It was a truly singular spectacle to see the float advancing against the wind, and sea, and current, with an average velocity of one knot per hour. The boatmen could not suppress their astonishment; it seemed to them as if some marine monster must be bearing the block along. An English officer, when crossing the Straits of Sunda in an open canoe, found himself carried away by a current. He threw into the water a bucket, loaded with a weight, which he caused to sink to a great depth, holding, at the same time, this novel species of anchor by a cord. It was not long before the boat became borne along in an opposite direction to that of the surface current. A submarine stream had, in fact, carried the bucket with such force as to overcome the surface current.

What facts there are in the history of the ocean which for ages remained unsuspected. What enigmas lie buried in that ever-moving mass. What problems to solve; what observations to follow up; what experiments to try, in order to unveil all the forces which set in motion the mechanism of the waves.

What sets in motion this mighty marine circulation? Is it due, as some assert, to the impetus of wind, and if not what is the cause?

The agitation of the air produces the superficial agitation of the waves; but how can the submarine streams, not thus affected by the wind, be set in motion?*

The vast wave produced by the tides occasions, no doubt, a vertical motion; but it is impossible that from this cause should be derived the movement of the Gulf Stream. The prime mover of the great oceanic machine is to be sought elsewhere. Where, then, is the secret power hidden? Whence comes the first impulse? Heat is the most obvious cause of marine circulation; but heat would not be capable of producing marine currents were it not for the salt which is dissolved in the water. In fact, salt is one of the chief factors in producing the circulation of the sea. So abundant is this ingredient, that were all the salt in the ocean collected and placed upon America, it would cover that vast continent with a layer 4,500 feet thick.

Evaporation carries daily from the equatorial seas enormous quantities of water, which rise into the air in the form of clouds. The superficial layers, rendered more saline by the evaporation and removal of fresh water, become denser and descend, to be replaced by lower strata of less specific gravity. Thus movement is produced. In the lower strata of the water there is at the same time a movement of the denser waters from the equatorial regions towards the poles.

It has been suggested that the motive power of some currents may reside in the infinitesimally small beings which

* There exist in the sea a great number of periodical and accidental currents, which derive their origin from the action of the winds; but we are not now speaking of these variable agitations. Among the periodical currents may be mentioned those which, from the 15th of May to the 15th of August, traverse the China Sea from east to west, and in the opposite direction from October to March.

people ocean. The madrepores are minute creatures, which, atoms as they are in the kingdom of Nature, may yet be of indispensable utility in her machinery.

These microscopic animals form gigantic coral reefs. Each joins its own minute handiwork to the completed work of the others. They secrete calcareous atoms, which become welded together, and increase so as to form archipelagoes,—perhaps, in time, to form the basis of large islands, or even continents.

Each one of these little creatures requires nourishment. It extracts from a drop of water the material necessary for its subsistence. It draws from the sea the calcareous matter which it requires. Thus the action of these minute animals reduces the weight of the water. The water, thus become lighter, is then set in motion by the pressure of the molecules that surround it. Each tiny being gives individually but a very feeble impetus—it is the impetus imparted by an atom. But the agency of the animalculæ is due to their united action. "Unity is strength," says the old proverb; and these zoophytes prove the truth of the maxim, by the enormous labours they achieve.

How are we to set down in figures, says Maury, the quantity of solid matter thus daily extracted from the sea? Does it amount to tens of thousands, or thousands of millions of tons? This is a question impossible to answer; but whatever the amount may be, the effect produced on the motion of the water is immediate; and we see that a species of animal, devoid of locomotion, the life of which is scarcely distinguishable from that of a plant, seems to be endued with a power which may be adequate to originate an ocean current.

Thus these streams of the sea, of which the track is followed by navigators in the midst of the vast ocean,—these currents, of which the source is frequently equally involved in mystery with their final issue,—these hidden arteries within the bosom of ocean,—this circulation, so irresistible, so vast, so imposing in its immensity, is notably set in motion by the heat of the sun, which by evaporation increases the proportion of salt in the upper layers of the sea; and possibly in some cases also by these imperceptible beings, which are incessantly at work in the ocean's depths.

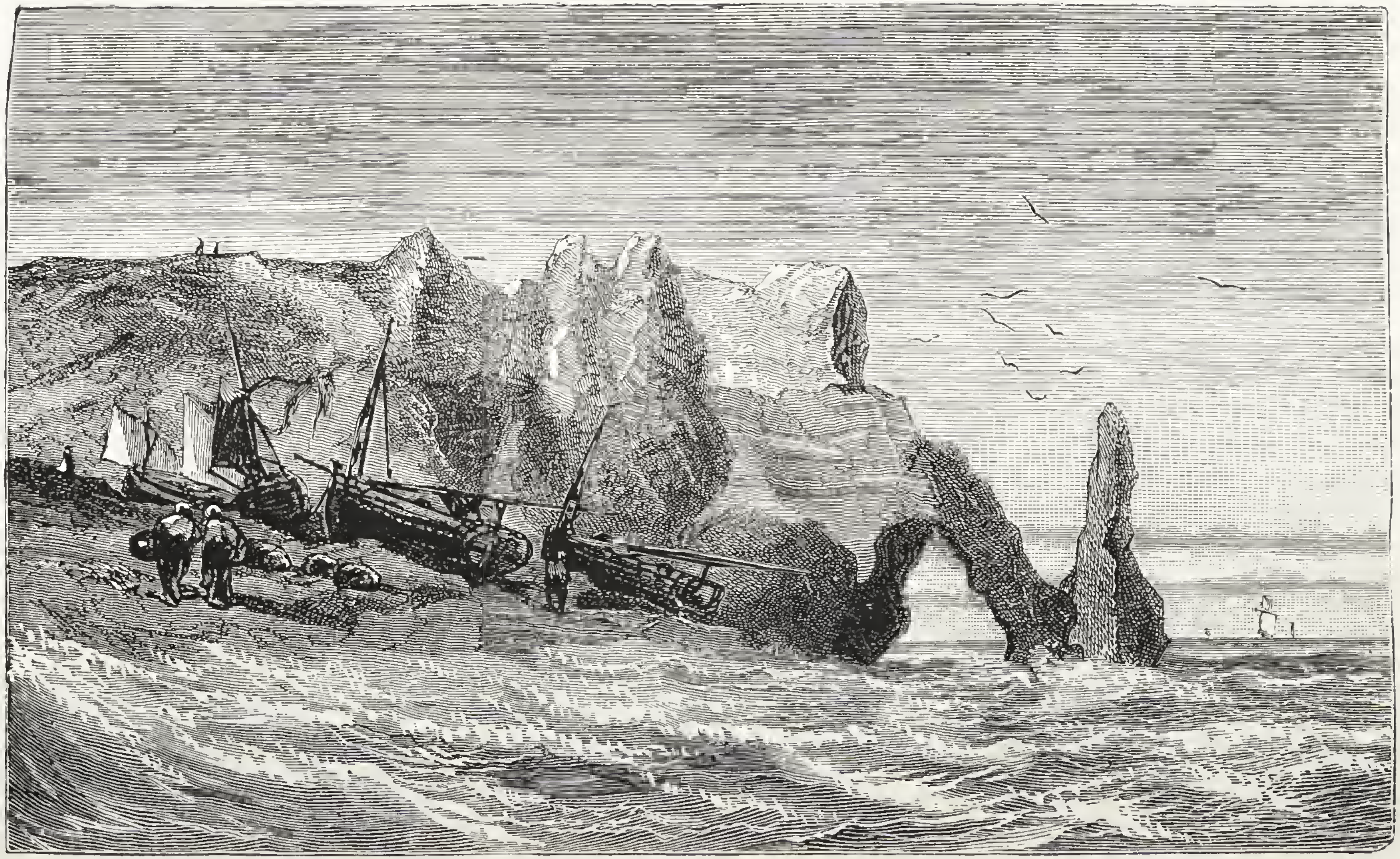

FIG. 3.—ACTION OF WAVES ON ROCK.

CHAPTER III.

THE DESTRUCTIVE AND FORMATIVE ACTION OF WATER.

THE waves wear away rocky shores, cut, hew, and shape the coast, waste and eat away the land; they dash against the feet of lofty cliffs, and daily encroach upon them by the landslips which are produced. Sometimes the waves cut, separate, and excavate rocks, thus giving birth to fantastic constructions bearing the impress of a style altogether unique—a grotesque order of architecture. (Fig. 3.) Let us quote a passage from a great author, who paints in magic colours the spectacle which this sea-built architecture offers to us:—"These structures," says Victor Hugo, "possess the sublimity of the cathedral, the extravagance of the pagoda, the amplitude of the mountain, the delicacy of the gem, the horror of the sepulchre."

The condition of maritime countries offer us numberless examples of the ravages and sharp modifications to which their shores have been subject, owing to the action of the sea. We can find striking proofs of this in the formation of the Zuyder Zee, in the curious effects which have modified in all parts the aspect of those islands which lie between the Texel and the mouths of the Elbe, in the indentations of the winding shores of the Cattegat and in the recesses of Lymfiord. Creeks and gulfs have been in the lapse of ages, produced under the potent influence of the waters. In other places we find the waves heaping up banks of sand and pebbles on the sea-shore, and anon destroying their own creations, causing the vast erections to disappear, to which the waves themselves have given birth.

The action of the waves does not merely exert its influence over a loose soil, but is felt by the hardest and most solid rocks. However abrupt and resisting be the shore, it is still gained upon by the irresistible element. Nothing is sufficiently strong to escape the army of waves, and the land is always defeated in its contest with the sea. She only triumphs when she avoids a battle, like Fabius with Hannibal. If she offers to the sea a flat and uniform seaboard, the waves advance gently up to the shore, and their wrath is appeased. Before an enemy who attempts no resistance, they lose their impetuous force, and quietly lay at her feet round stones and fine sand—creating more than they destroy.

The natural configuration of coasts is favourable to the action of the waves, when the stratifications of the soil offer to the sea superimposed layers, of which the lower part—continually attacked by the liquid element, everlastingly shaken by the reiterated influence of the waves—is removed the quicker from some special facility with which the material can be disintegrated. The upper layers menacingly overhang, and form frowning prominences, which, ere long, precipitate themselves into the sea. (Fig. 4.)

Of all the shores beaten by the tempest, there are none which present a more imposing appearance, or give a more

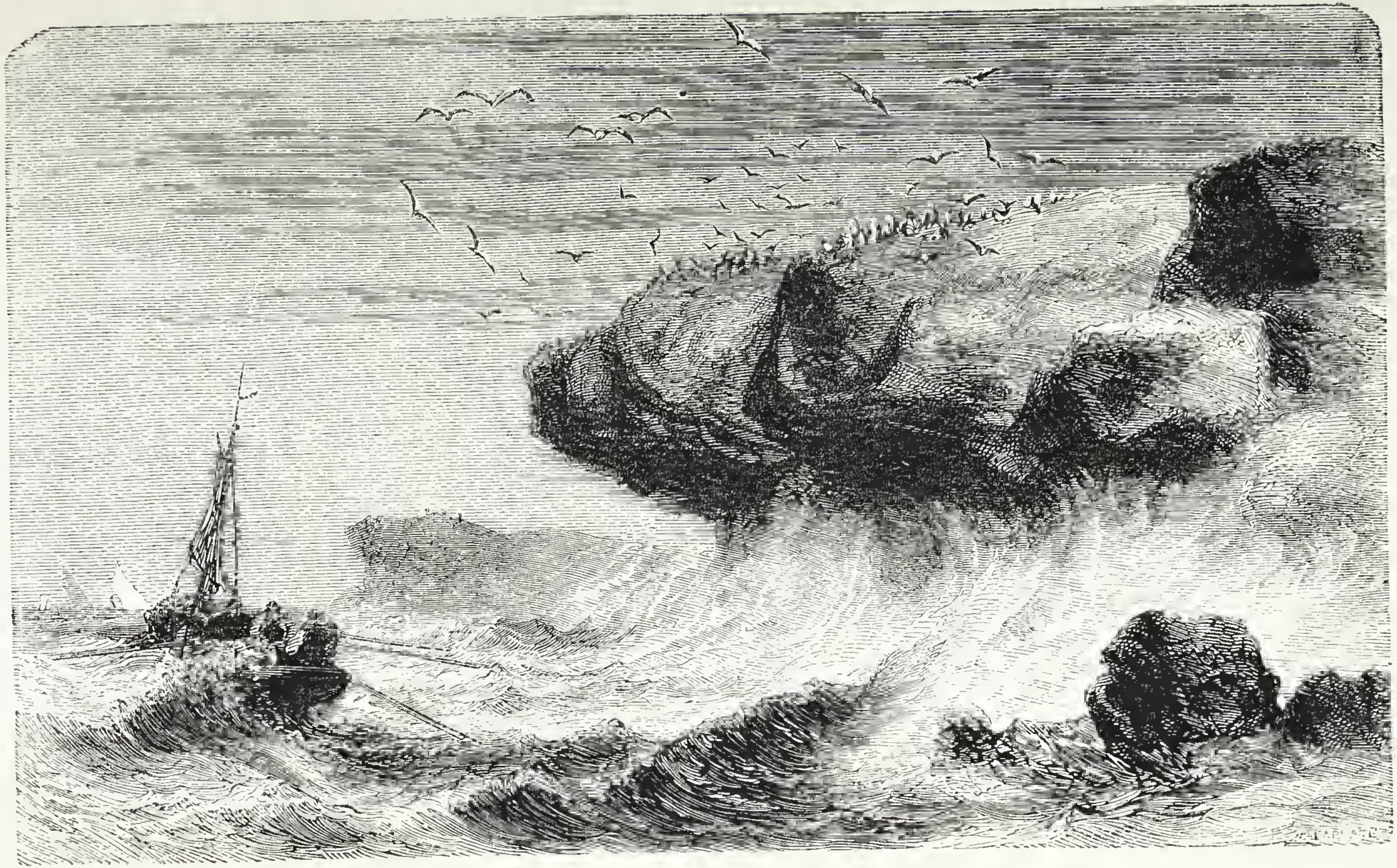

FIG. 4.—UNDERMINING ACTION OF WAVES (QUIBERON).

vivid idea of the power of the waves, than do the fiords of Northern Europe and of America. These fiords are deep bays, long and narrow indentations, which leave between them vast rocky peninsulas. We might liken such coasts to an enormous fringe, of which every thread is a peninsula. So high is the escarpment of these coasts, that Mount Thorsnuten, situated to the south of Bergen, attains at one spot on the shore a height of 5,200 feet. In a great number of these bays cascades and waterfalls descend from the summits of the cliffs and rush into space, forming on their way a parabola, beneath which fishing-boats have free room to pass.

It has taken the ocean perhaps many thousand years to chisel all these marvels and to sculpture these rocky labyrinths, and it is possible that deluges and earthquakes have, at various epochs, aided in their formation; but, even in our own day, at every hour, at every instant, the sea is dealing its blows against the coast. On the summit of a lofty cliff the observer can, in the midst of the tempest, obtain a good idea of the encroachments which are made by the fury of the waves. The billows rush against the shore. Blocks of stone shake from base to summit. The work of demolition can be seen by glimpses through clouds of spray and foam.

When once a calm has succeeded to the tempest, and agitation gives place to repose, it becomes possible to measure the inroads of the sea, to note the advance of ocean, and to calculate the weight of the rocks which the waves have crushed. During seven centuries the waters of the Channel have invaded 4,500 feet of land, and the cliffs, which now tower over these shores, have consequently receded nearly a mile since the period when Peter the

D 2

Hermit preached the first crusade. The Straits of Dover widen day by day.

We have already remarked that the inclination of strata opposed or assisted the action of the waves; the hardness of rocks and the chemical composition of their molecules also cause variations in the rate at which they are worn away.

The cliffs do not resist the efforts of the ocean merely by the hardness of their materials. They often take the precaution of clothing their bases in armour, by way of defence against the repeated attacks of their enemy. An abundant vegetation of algæ and marine herbs carpets every fissure of the rocks with a fantastic covering of hair.

Where the waves are sufficiently powerful, enormous blocks detach themselves from elevated strata; they become broken by the shock of their fall, and are swept away by the waters, which retire and seem as if taking a new impetus before recommencing the attack. The rocks become broken into small fragments, and ultimately are rounded into pebbles; and the heaps of debris thus raised afterwards protect the rocks from which they have been torn, and produce the shelving banks which put a stop to the conquests of the sea. Might we not liken them to so many corpses heaped round the fortress, whence the enemy has succeeded in forcing them?

On the shore of the Mediterranean, near Vintimiglia, and also on the coast of Brittany, there is to be seen a mass of ruins of this description, which resist the efforts of the waves. (Fig. 5.) Examples need not be added, everywhere we find the sea busied in levelling the cliffs; it lowers the promontories and heights of the coast, and deposits their dust at the bottom of its vast empire.

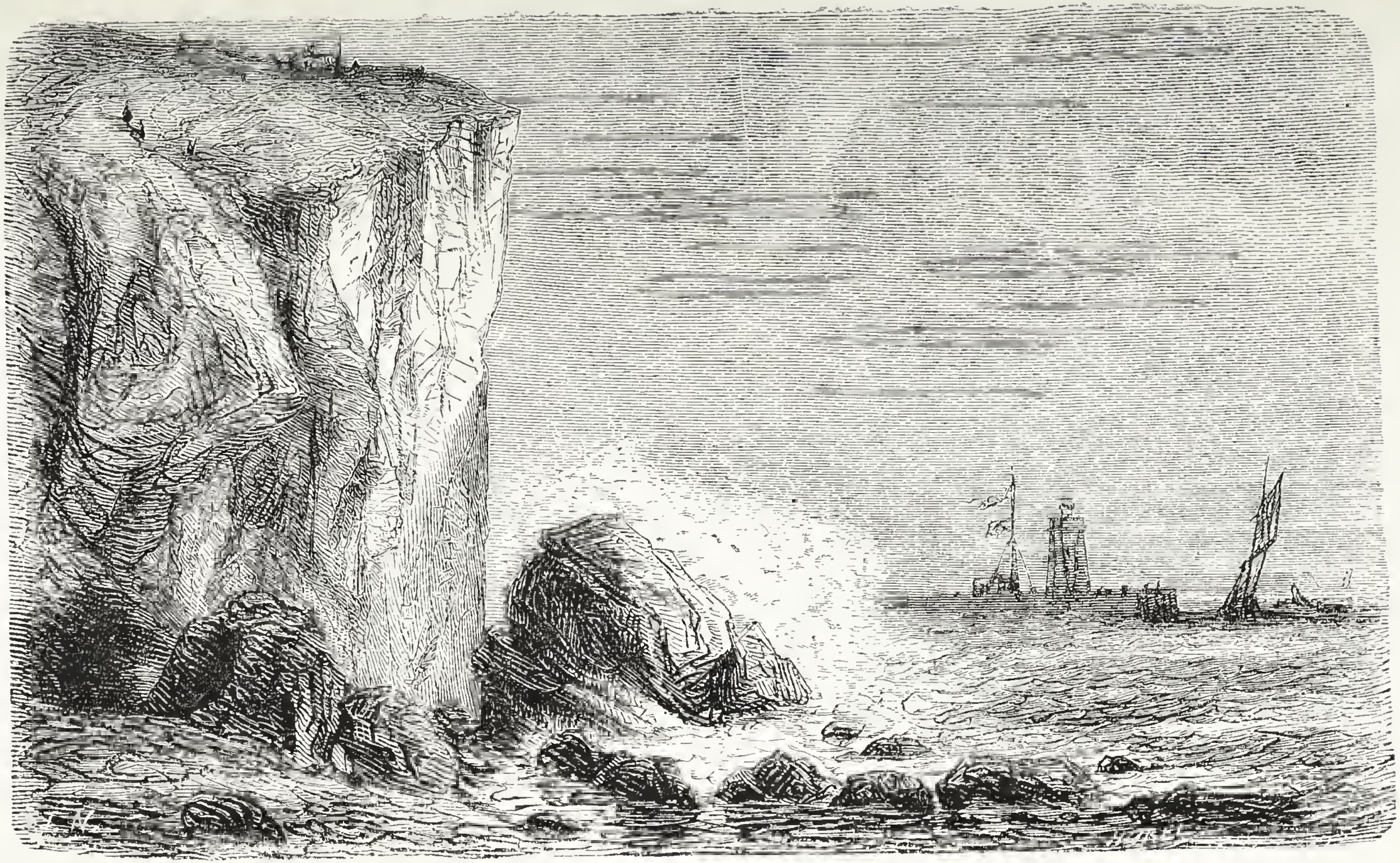

FIG. 5.—MASS OF DEBRIS PROTECTING ROCKS (FECAMP).

Reproductive Effects.

If the action of the waves exercised merely a destructive effect, it must ultimately be followed by a complete annihilation of continents; but the sea repairs to some extent the ravages which it has caused. The waves break down and comminute the rocks on the seashore; but the debris thus made is not lost; it is transported to other places, where it forms superimposed layers. The quantity of solid matter held in suspension by the currents of the sea is so considerable that, in order to raise the level of the soil in certain districts, the water carried up by the tide is caused to flow upon the land. By frequently repeating the operation, large estates which border on the Delta of the Humber have been elevated six feet. The tides fill up in this way the cavities and hollow places which corrugate the bottom of the ocean, by means of the sediment which they discharge into them.

At the upper end of the Red Sea it has constantly been remarked that the Isthmus of Suez has increased in size with extraordinary rapidity, owing to oceanic deposits. This isthmus, as we are told by Sir Charles Lyell, has doubled in width since the time of Herodotus. At that period, the town of Hieropolis stood on the seashore; in our day it is as far from the Red Sea as from the Mediterranean. It is situated exactly in the middle of the isthmus. In 1541, Soliman II. found in the port of Suez a valuable harbour of refuge, capable of giving shelter to his entire fleet. Now an immense bank of sand has replaced the channels of which his vessels availed themselves. In eighteen hundred years, the territory of Tehama, situated on the

Gulf of Arabia, has received from the sea a tribute of two leagues of soil in sediment, which has gradually increased from age to age. If we penetrate further from the shore into the land, we find at a certain distance from the existing sea-ports, the ruins of ancient ports, which flourished long ago, under the same names, and the remains of their walls, once washed by the sea, serve now as obstacles to the invading progress of the desert sands. One part of the delta of the Nile is day by day encroached upon by a powerful current of the Mediterranean, and the waves carry to a considerable distance the valuable loam drifted along by the earthy stream. They transport the solid matter as far as the shores of Syria.

M. Girard, an eminent man of science, who, at the time of the French expedition into Egypt, was commissioned to make investigations as to the remains of the canal of Amrou, is of opinion that the whole isthmus of Suez is of oceanic formation, and considers it as a vast dam, constructed by the marine currents. Although, indeed, this opinion is open to objections, it is none the less certain that that isthmus, now become celebrated from the works which have been so successfully carried out there by one of the most able intellects of modern times, constantly increases in width, in consequence of the continual augmentation of the deposits, which are heaped up on the shores.

Examples of this description abound. The shores of Guiana increase and gain upon the dominion of the ocean, as in other parts of the world the sea inundates and encroaches on the land. It is the oceanic currents which brings to those counties the sediment which has been borne from the delta of the Amazon. The transport of earthy materials by the waters need be no matter of astonishment when we remember the state of extreme subdivision into which the solid substance becomes reduced. Fine emery powder, for example, will remain for a long time in suspension in water, and will take more than an hour to fall to the bottom of a vessel one foot in height. It may be inferred from this that if the marine currents carry with considerable velocity upon the surface of the ocean an extremely fine earthy powder, that as this powder only sinks very slowly through the fluid which carries it away, it will be transported to a very great distance before reaching the bottom of the ocean.

Thus the sea, which wears away our continents with so much violence, does not merely carry on a work of disintegration; but, after having demolished the land with its ruthless blows, after having invaded the shores, the sea transports to other coasts a sediment which compensates for the wounds which have been inflicted elsewhere.

But the land itself is not incapable of opposing a vigorous defence to the action of the waves by the gradual motion with which, in many parts, it is endowed. The subterranean fires which have in past ages corrugated the earth's surface are far from being extinct, and earthquakes and other convulsions are from time to time spreading terror over some parts of the globe. But these abrupt movements, these tempests in the realms of Pluto, are the exceptions, even as the hurricane is the exception to the rule which directs the movements of ocean. During an earthquake the sea loses its surface equilibrium; it becomes subject to terrible oscillations, and its waters invade the land, producing formidable convulsions in the countries which they inundate. The histories of the Greek Archipelago and the islands of Japan are replete with accounts of such disasters.

But subterranean fires seldom act in a manner so violent; they usually lift up the earth gently, and raise it in an insensible manner. The hand of a clock appears immovable at a glance, although it traverses in one hour completely round the dial. It is the same with the shores of many continents; urged by an invisible agency, they slowly perform an upward and regular progress, and repulse the waters of ocean.

Numerous are the writers who explain certain phenomena of the sea by saying that the water has retired, that it has abandoned its bed, and that the immovable shores have seen their empire extended through the flight of the liquid element. The level of the sea is really immovable, but we are sometimes deceived by appearances. The water, always agitated on its surface, appears to us the image of instability, whereas it is endowed with a remarkable fixity; and the earth, according to Pliny the emblem of immobility, is, on the contrary, endowed with motion. The ocean never retreats from the shore. It is chased thence by the shore, which is rising.

The ocean does not slowly invade certain coasts; it arrives thither by a forcible advance, to which it is impelled by the actual lowering of the shores beneath the sea level. Let us take care not to trust too much to the unreflecting testimony of our senses, but to view facts with the eye of reason, and we shall then find that ideas are not less real and incontestable because they are contrary to generally received opinions.

The laws of hydrostatics teach us that what we term *the sea level* is a surface of equilibrium, determined by the forces of attraction exercised by the globe upon its liquid portions. It is impossible for the waters to rise or fall in any place whatever in a continued manner, without all the other parts rising and falling through precisely the same amount.

Now we are acquainted with a great number of places in which the sea has not been subject to the slightest change since the commencement of our history. The general surface of the sea has, therefore, not changed, and the constancy of the liquid level which covers almost entirely the surface of the globe is a positive fact. How otherwise can it be accounted for that from 1822 to 1837 the sea had abandoned the shores of Chili (as, indeed, it appeared to the inhabitants of these countries), and that no variations were felt on the neighbouring coasts of Peru and California? How is it conceivable that the sea should have risen in the lower part of the Gulf of Arabia, in the Straits of Messina, and on the coast of Portugal, while it has remained immovable in the adjacent parts of the ocean? Instead of speaking about the immutability of the earth, it would be more correct to speak of that of the sea. It must, therefore, be conceded that the level of the ocean is unchangeable, and that the solidified surface of our planet is susceptible of elevation, of depression, and of every kind of modification.

We have here an error very similar to that which, during so many centuries, was prevalent with reference to the supposed immovability of the globe. Our eyes still show us the sun revolving round our planet; but science has shown how our own small globe performs its journey round the sun, which warms it, in an ellipse from which it never swerves.

Like many truths, that which we announce here, remained long unsuspected, and the lowering of the sea's level was a received doctrine of the older naturalists. In 1731 the Academy of Upsala resolved to test this important fact, and to try carefully all the experiments which could solve the problem. Notches were cut at high-water mark on rocks washed by the Baltic Sea; and, some years after, it was demonstrated that these marks had risen some inches higher than the surface of the sea. From this fact, it was proved that the level of the Baltic had considerably sunk; but these conclusions met with strong opposition, and fresh experiments were tried. The ultimate result arrived at from all these experiments was, that on various parts of the same sea the level of the water was subject to an apparent depression, more or less sensible, on different shores; and that in other parts (the coast of Scaura) the level of the sea was rising, because the notches cut before on the rocks at high-water mark, were now found to have disappeared beneath the surface of the ocean. It is impossible to reconcile these enormous variations in so small an extent, because we would have to suppose that the level of the ocean formed an undulating surface. It is evident from these considerations that the level of the Baltic has not varied more than the level of other seas; but that in Finland and some parts of Sweden the surface of the earth has risen little by little, and is gradually elevating itself, without having received any perceptible shock; while the southern coast of the same peninsula is gradually lowering. The shores of Greenland have during the last four centuries been slowly descending, and are becoming submerged by the ocean. The Temple of Serapis, on the coast of Puzzuoli, is another striking instance of the movements of the land. The temple, built in a very lavish style of architecture, was certainly not originally erected upon the margin of the sea, where its columns would have been incessantly buffeted by the waves; it is now, however, to be found on the very edge of the shore. The three columns, which are the only remnants now remaining, present, at the distance of ten feet above their base, a zone perforated by shell-fish, which can only have entered the stone when submerged. Thus this temple, built upon a site completely sheltered from the waves, was afterwards plunged ten feet below the water, and has again been placed on the sea level by the oscillations of the land. Many are the islands of the Indian Ocean which have risen up from the sea, and which are now slowly returning thither by means of a gradual depression; whilst other volcanic islets appear on the surface of the waste of ocean, like the immense back of some gigantic sea-monster. In our own days, the fortuitous apparition of the volcanic island, which surged out of the waves in the midst of the Greek Archipelago, seems to warn us that the forces of Nature allow themselves no prolonged repose; and that the subterranean fires, which long ages back corrugated the land, and covered it with scars and wrinkles, are always in action beneath our feet.

The strife of elements, the combat between fire and water, materially alter, day by day, the aspect of this our earth.

BOOK II.

THE SYSTEM OF CIRCULATION.

CHAPTER I.

THE JOURNEYS OF THE WATER.

"What spectacle is more beautiful than to see the waters traversing the skies and return to the earth in the form of rain to quicken and revive the plants, give birth to fruits and grains, and nourish trees and vegetables?"—*Pliny.*

THE navigator who leaves Europe in order to cross the ocean, sees an entire change in the aspects of Nature as he approaches the equator. He there finds a region where thick clouds obscure the sky, and shed heavy rain on the waters below; yet, without this curtain of vapour to oppose a barrier against the burning rays of the sun, the traveller would be overpowered by the intolerable heat. The gloomy seas on the line were formerly the terror of sailors, for these masses of vapour have a depressing effect upon the minds of those who venture into these remote regions. These thick clouds, however, which thus hover over the equatorial seas, are really beneficial to the earth. This band is the real source of the rivers which water our fields—the floating reservoir from which escapes all the water which refreshes and revives our continents.

It is a well-known and important physical law, that every mass of water, surrounded by air, perpetually exhales into that air a quantity of vapour, the amount of which is greater when the temperature of the water is greater.

It may, therefore, be conceived how, under the influence of the burning tropical sun, the seas of the torrid zone emit continually an enormous amount of vapour. A thin mist rises from the liquid surface, ascends into the air, and gives birth to the black and sombre vapours that obscure the equatorial atmosphere.

When once these clouds have gained the higher regions of the air, where the temperature is sufficiently low, they return in part to their liquid state, and again fall into the sea in the shape of rain. But the uncondensed vapour, in consequence of its lightness, is carried in the higher strata of the atmosphere by currents directed towards the poles. These currents transport the moisture to our own latitudes, where it dissolves in rain or condenses in the form of snow when it meets the frozen summits of the mountains.

Thus a great distillation is at work all over the surface of the globe, the burning rays of the tropical sun acting as the furnace which heats this alembic. The Equatorial Ocean is the boiler of the immense apparatus; the cold atmosphere, the frozen summits of the mountains of the North, and the glaciers of the poles, form the refrigerators. The streams, the rivers and the lakes are the receivers, which are incessantly filled by enormous volumes of water, to be again restored to the ocean. This distillation is for ever being repeated; the water of the receiver being always sent back again into the boiler, to be submitted to a new process of distillation.

The noble river, which is poured into the sea, has therefore received its transparent fluid from the ocean itself. The pure beneficent water from the crystal spring, is none other than the salt water of the sea, purified in the great laboratory of Nature. The water came, no doubt, from tropical regions, accomplishing its journey under the form of light vapour; but, after its metamorphosis into rain, it came down again to earth, and made there for a time its abode. As water, it quenches the thirst of those living beings who surround it; nourishes the grass that carpets its margin; and, when once its mission is accomplished, it descends along the course of a stream, and returns to the vast ocean.

The sea has been aptly compared to a miser incessantly bent on adding to his hoard—it does not restore what has been stolen during a shipwreck, and if it lends to the earth the water, which is necessary for the support of life, it is only to exact afterwards a full payment of the loan. All returns to the vast reservoir: the very breath which escapes from our lips only rises into the air to become condensed into a drop of water, which the sea will ultimately absorb.

In travelling across the earth, and through the air, water is also commissioned to distribute heat over the globe, and to modify the temperature of climates. In escaping from the equatorial seas, the moisture absorbs the heat lavished by a burning sun, and, borne by atmospheric currents, this vapour distributes the heat over cold countries. Under the influence of gentle rain the climates of Northern latitudes are mitigated, and thus every animated being receives that vital warmth of which the sun is so lavish under the tropics, but which is distributed so much more sparingly in countries nearer to the poles.

Before the water finds a high road to the sea by the streams, it traverses the earth, penetrates into the little channels which are formed by the fissures in the soil, percolates into porous ground, glides through cracks in rocks, seeks its way through interstices between flints and pebbles, creeps between the roots of plants, rises up their stems, insinuates itself into their cellular system, dissolves and takes away from the soil the mineral materials which it meets with on its course, and conveys them to living beings who assimilate them. At times it unites itself to minerals, and makes its abode with such substances in combinations which are called hydrates. Now it rests immovable in marshes, and anon labours to decompose organic matter, aiding in the putrefaction and decomposition of the materials from which turf is made.

Water seldom remains stationary for a long time; after having, in a liquid state, traversed the bodies of animals, or the stalks of vegetables, it becomes exhaled in vapour. Thus it again escapes and returns to the atmosphere, which it will quit in the form of rain, hail, or snow, to commence again its everlasting round.

A true Proteus, water is constantly changing its form. It is the sap of vegetables, and the dew which lies in pearls on the grass; it is the blood which circulates in our veins; it is the frost which draws a thousand fantastic patterns upon our windows; it is the stream which propels our water-wheels, and the fog which rises from the swamp. It is indispensable to the existence of all organised beings.

Water, vapour, and ice—in these three forms the substance is always found. It never leaves one but to take another. Water quits the ocean to irrigate the dry land; it deserts the continents to return to the empire of the waves; it flies through the air, creeps upon the ground, flows within the sea. In one form water is committed to the light breeze. In another it follows the declivity where it may happen to find itself; it penetrates into the crevices of the earth, warms itself in their depths, and bursts out again, boiling and impetuous.

Water wears away and polishes the rocks over which it flows; it transports from one country to another the minute seed of a plant, the egg of an insect. Water carries away trees and stones along the bed of the torrent, heaps up sand and pebbles on the shore, and undermines and wears away the solid cliffs.

The poets have often looked upon water as being the emblem of inconstancy and mobility. The fluid part of the globe is, indeed, subject to constant agitation. If water be on a slope, its weight carries it down with a speed depending upon the inclination, whence originates the torrent, the stream, the river.

The waves produced by the action of the wind upon the sea which glide up to the shore and then die away, the miniature cataracts formed by the streamlets which run between the stones on the beach, present, apparently, the spectacle of free and uncontrolled motion. But the great movements of the sea are not capricious, their obedience to law is perfect. The circulation of water on the earth is as regular as that of the circulation of the blood in animals. The movement of water in rivers may be likened to that of the blood in our arteries, and the transformation of salt water into fresh water may be compared to the constant metamorphosis between arterial and venous blood.

What can be more wonderful, and, at the same time, simpler, than the journey of a drop of water, exhaled from the ocean, which traverses the atmosphere, and falls to the earth in rain? After having drawn both from the air and the soil nourishment which it has imparted to living creatures, after having animated all things on its way, it returns to the ocean to commence anew its beneficent career.

CHAPTER II.

WATER IN THE ATMOSPHERE.

THE air, even when it is pure, transparent, and azure, is an immense reservoir of vapour; it is a vast gaseous sea, which covers the earth on all sides to a depth of more than forty miles, at the bottom of which live animals and plants.

The surface of the sea, as we have already remarked, emits constantly into the air a vapour indispensable to the needs of life. Air too dry we should not be able to inhale; it would parch up the lungs, injure plants and animals, and produce the bad effects we know to result from the simoon of the desert. At the same time a too damp air has also its disadvantages. Every one has heard of the malaria of certain warm and humid localities.

Visible clouds and fogs are frequently confounded with the vapour of water, but that is a grave error. Uncondensed vapour is an impalpable gas, which the atmosphere in combination with the waters of the sea is constantly generating. Its presence in the air is constant, but the amount is in variable proportions. Vapour exists usually in almost infinitesimal quantities, seldom forming more than one half per cent. of the total mass. It is almost incredible how much this slight element of watery vapour affects the meteorological phenomena of the globe. It exercises an enormous influence on the radiation of heat, and Tyndall tells us that in England, on a day of ordinary moisture, the atmospheric vapour exercises an action at least one hundred times greater than that of the air itself. It is by the power of absorption that the vapour acts. The surface of the earth tends to lose by radiation the heat which it has absorbed, but the aqueous vapours contained in the air take up that heat, warm themselves by it, and clothe the earth with a mantle which secures it from a cold which would be fatal to every living creature. Wherever the air is very dry (it is never completely so) we are subject daily to great extremes of temperature. In the daytime the rays of the sun penetrate towards the soil without meeting obstacles which arrest them. The rays warm the ground and produce a high degree of heat. In the night, however, the earth radiates this heat back again to the sky, and the result is a nocturnal temperature extremely low. In the steppes of India, on the tablelands of the Himalaya, in the plains of Australia, in every country where the climate is very dry, excessive heat during the day alternates with bitter cold at night. In the midst of Sahara the rays of the sun raise the temperature of the ground so much that it is impossible to place the hand upon it, while at midnight the cold is so intense that water, if it could be found in so arid a climate, would be frozen. The difference of temperature arises from this, that the air, deprived of vapour, cannot arrest the flow of heat. The vapour ot water is a transparent cloak to the earth: it partially intercepts the rays of the sun, and prevents their acting with too great force. On the other hand, when the sun has disappeared beneath the horizon, the cloak does not permit the heat which has been absorbed by the ground to escape into the celestial space, and it thus protects living beings from cold.

It may be objected that this vapoury mantle which preserves us from the cold must at the same time prevent the solar rays from reaching us. This is not altogether true. The vapour of water is a screen which arrests the earth's heat more perfectly than that radiated from the sun. The obscure rays emanating from the earth differ from the luminous ones derived from the sun. The moisture absorbs the former in much greater abundance than the latter. A piece of glass permits the light to pass, but partly arrests the heat which accompanies the light. In the same manner the vapour of water interrupts the obscure rays, whilst offering a comparatively free passage to the luminous rays, and its absorbent power is especially exercised on the heat which is emitted by the earth. In consequence of that admirable and marvellous influence, the mean temperature of our globe is higher than would otherwise be the case.

Fogs.

Nothing is easier than to deprive the air of the water which it contains; it is only necessary to cool the air, and its vapour condenses as in the refrigerator of a distilling apparatus. A decanter of cold water placed in a warm room will become covered with a coating of dew. So it is in nature; when the temperature of a mass of air becomes lowered in consequence of the disappearance of the sun from the horizon, a point is reached at which the vapour becomes condensed into drops of extreme minuteness. Our breath produces in cold localities a visible cloud. The steam which escapes from a railway engine gives birth to a series of similar little globular vesicles. An infinity of these small invisible spheres, which are like miniature soap-bubbles, constitute fogs and clouds. Physicists are not agreed as to the nature of these vesicles. According to some, they are little balloons swollen by vapour of water; while according to others, they are merely spheres of water without any internal cavities.

To fogs has often been attributed the origin of certain maladies, and an influence inimical to health. It is evident that fog is the indication of a superabundance of humidity in the atmosphere, and that it is usually formed in the midst of a mass of air in repose, where impure emanations accumulate easily. In marshy countries it is by no means unusual to find frequent fogs followed by an epidemic of fever among those exposed to their influence.

Clouds.

Clouds are fogs situated at a certain distance above the earth. But there are some clouds formed, no longer of vesicles, but of small needles of ice. Clouds have a proverbial mobility, and their classification is almost impossible. Some meteorologists have, however, tried to discover certain leading types among the numerous forms which these masses of vapour assume. Four sorts of clouds have been distinguished—the cirrus, the stratus, the nimbus, and the cumulus (Figs. 6, 7, 8, and 9). We do not insist upon these classifications, which are of little importance, because every cloud has its particular shape. A wreath of vapour detached upon a blue sky is subject to all the caprices of wind, and assumes an endless variety of forms.

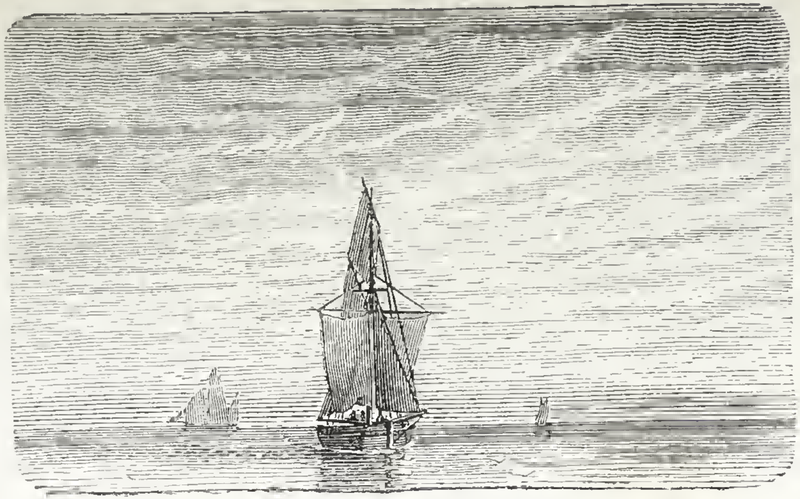

FIG. 6.—CIRRUS.

FIG. 7.—STRATUS.

FIG. 8.—NIMBUS.

FIG. 9.—CUMULUS.

CLASSIFICATION OF CLOUDS.

Condensation of Vapour of Water—Rain—Snow—Dew.

Of all the methods of warming or cooling air there is none more efficacious than to compress or dilate it. Many are familiar with the experiment of the air tinder-box. By means of a piston we strongly compress the air in a tube with thick sides, and this air becomes sufficiently warm to set on fire a piece of tinder.

Nature cools the air by dilatation, and thus water is formed in the state of rain by the condensation of vapour. This is effected by carrying the air into the higher regions of the atmosphere, where there is less pressure. The dilated air becomes cold, and precipitates the vapour in the condition of hail or snow, if the cooling be sufficient.

If we imagine a wind to blow regularly in the direction of a mountain or a forest, the damp air meeting with an obstacle does not the less pursue its course. It surmounts the obstacle, and lifts itself into those regions where the pressure is less, thus producing rain. It has been frequently remarked that when a current of air moves towards a forest, the vapour it contains will condense in rain. Should the obstacle be more lofty, like a mountain, the lowering of the temperature is more considerable; the water solidifies instead of liquifying, and forms snow, or hail. At sea the effect may be produced by the action of atmospheric currents, which, meeting in opposite directions, displace considerable volumes of air, and produce a like result. A primary condition of the production of rain is, therefore, a movement of the air; but the matter is complicated by the direction of the wind and the level of the ground.

We may observe, further, that at present the science of meteorology is in a very backward condition. There is, however, reason to hope that at some future time the laws which preside over the movements of the air and the distribution of rain will be discovered.

The condensation of vapour does not take place only in the mass of the air; it may be produced on the surface of bodies on the ground. The phenomenon takes the name of *dew* when the vapour condenses into water, of *rime*, or *hoar-frost*, when it assumes the solid form.

It is to Dr. Wells that we owe the explanation of these various phenomena. During the night bodies become cold in consequence of radiation, and the vapour of water condenses on them. The more damp the air, and the more pure the sky, the more strongly is the phenomenon produced.

FIG. 10.—SOURCE OF THE APURIMAC.

CHAPTER III.

THE ARTERIAL SYSTEM OF CONTINENTS.

WE have followed the drop of water which we saw escaping from the ocean under the form of vapour, abandoning itself to the breeze, allowing itself to be cradled on the ever-moving air, and returning to be condensed into water or ice in the higher regions of the earth's surface. Let us now come and watch the melting of the eternal snows which crown the mountain-top, and the formation of the thousand brooks, the innumerable torrents, which descend down the slopes of the earth, and wind, serpent-like, upon its surface; let us follow the liquid veins to the rivers with which they at last blend their waters. Let us observe the rain which penetrates into clay or flint soils, and which in other parts lodges in the cavities of the ground. Let us be present at the river's source: we shall see it escape between herb and flower, a stream in miniature, a crystal thread which is the embryo of the river. Let us walk upon its banks and listen to its murmur: nor shall we doubt the possibility that this little brook, so modest and so slender, will swell into a mighty river.

But as we descend along its course we shall see tributary streams join to swell its waters and to feed the liquid which glides along its bed. The banks separate little by little, the volume increases, and ere long a majestic river flows through countries numerous and rich. "In its triumphal march," says Goethe, in his Song of Mahomet, "it gives names to the countries which it waters; cities rise at its feet. Rapidly it rushes on its irresistible course, forsaking, as it speeds along, the gilded tower and marble palace, which to the river owe their origin. This second Atlas bears upon its bosom stately structures of cedar, while a forest of flags, witnesses to its glory, float upon its surface."

The sources of some of the greatest rivers are reservoirs of no great extent; but which, embedded in the mountains, form the natural receptacles of the rain and melted snow. The sources of the rivers Apurimac and Camisia in Peru (Figs. 10 and 11), and that of the Rhone in the Alps, are striking examples.

Chains of mountains prescribe the routes which rivers must take. The lofty summits of the globe collect the waters of the ocean, and pour them down their sides in the direction of the sea. Mountains are not irregularly scattered on the earth's crust, but in definite mountain chains, which possess a certain amount of regularity.

In the continent of the Old World the chains of mountains take a direction principally from east to west, while those chains which extend from north to south are comparatively secondary branches. This fact in the distribution of mountains has its effect on river systems. The Euphrates, the Yellow River, the Blue River, all the great water systems of China, travel from west to east, and the chief arteries of all our Old World continents have generally speaking the same

FIG. II.—SOURCE OF THE CAMISIA.

direction; the larger streams of Africa and Asia extend either from west to east, or from east to west, the Nile being the principal exception.

The continent of the New World presents the same appearance of regularity in the distribution of the liquid arteries which traverse it. An enormous chain of mountains divides America into two great watersheds; the waters which glide down these immense declivities directing their course towards the sea either to the east or to the west.

Such is the general view, the spectacle which the irrigation

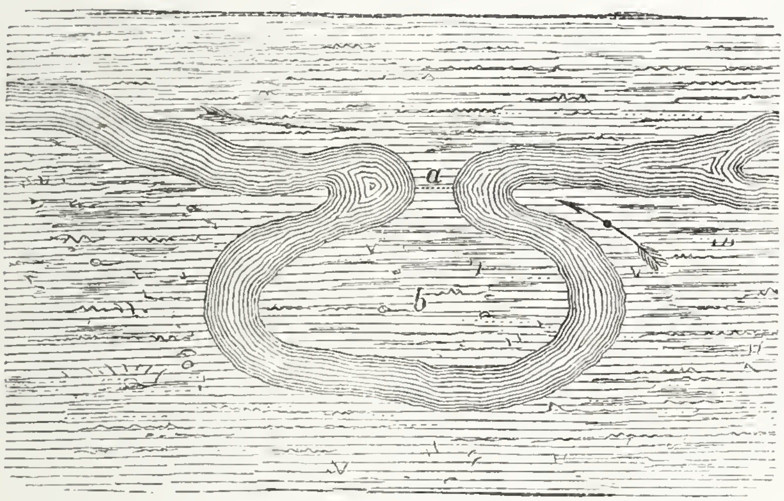

FIG. 12.—CURVE OF THE COURSE OF A STREAM.

system of the world presents from a distance. In examining this system more closely we perceive that the rivers pursue their winding courses with singular irregularity, alternately winding and contracting, following now a straight and now a curved path, describing a thousand sinuosities, meandering through the valleys, becoming confined between rocks and narrow channels, gliding rapidly down slopes, murmuring softly in shallows, rushing in rapids, leaping down in cataracts, and reposing in lakes.

The mere force of the current of a river is able to modify the aspect of the route which it describes. Fig. 12 represents a curve traced by a course of water; the current winds back on itself, and the isthmus (*a*), constantly worn away by two opposing currents, will ere long cease to exist, while the peninsula (*b*) will become an island.

Rivers usually widen as they proceed on their journey from the source to the mouth. The curves which they describe often become more numerous as the stream approaches the sea. In the interior of countries rivers frequently take a straight course, while, as they near the coast, they describe numerous curves and wind backwards and forwards. They return towards the continent, and anon change again towards the sea, so that in a small space the stream may run in totally opposite directions. It appears as if the generous river felt dissatisfied at not having sufficiently benefited the territories through which it has passed, and seems unwilling to forsake the continents which it has been fertilising.

Length and Depth of Rivers.

The greatest rivers of Europe are: the Volga, which has a course of 2,762 miles; the Danube, 1,722; the Don, 1104; the Dnieper, 1,243; the Vistula, 598. In Asia the river Yang-tze-kiang has a length of 3,314 miles, and the river Amur 2,739.

The Senegal, in Africa, accomplishes a journey of 960 miles; the Nile has a course of about 2,578 miles in extent.

America has the largest arterial system of any part of the world. The Mississipi fertilises the countries which it traverses to a distance of about 1,930 miles, and the superficial extent of its basin is more than seven times that of the

FIG. 13.—MOUTH OF THE AMAZON.

whole French empire. The width of the great American river varies from 274 to 823 yards from the Falls of St. Anthony to the confluence with the Illinois; the width reaches 2,286 yards at the confluence with the Missouri, while it is about 1,372 yards between the confluence with the Arkansas and New Orleans. The depth of the Mississipi is from 50 to 60 feet at the confluence with the Ohio, and from 200 to 260 feet between New Orleans and the Gulf of Mexico. The current travels at the rate of four miles an hour, and during floods vessels find a difficulty in ascending the stream.

But yet more majestic is the vast stream of the Amazon, which joins the waters of the Atlantic by an estuary 186 miles in length (Fig. 13). All is colossal about this river, which restores to the sea the rain and snow deposited in a basin of fully two million square miles. So deep is this river that a line of 300 feet in length cannot always fathom its abysses. With its tributaries it provides 50,000 miles of inland navigation. The Amazon is, in fact, a fresh-water sea, which at flood time moves at the rate of nearly four miles per hour, and contains a volume sufficient to supply 3,000 such rivers as the Seine.

Among the most rapid rivers are the Tigris, the Danube, and the Indus. These watercourses receive into their channels a great number of rivers, which form more or less extensive ramifications round the main artery. The Danube, for example, receives into its bosom above 200 rivers or brooks.

If the sea were to become dry it would take the rivers of the world 40,000 years to fill again the vast basin of ocean.

Shores and Floating Islands.

What a variety of aspects, what a diversity of features is presented to us by the course of rivers. The blue or rosy-coloured waters of some glide along over a bed of flints, while others flow in yellowish waves over a muddy bed, some rivers meander over a fertile soil, and slide by hills enamelled with every description of vegetable productions, while others again dash over sharp rocks, or languish amidst the sand of the desert. In our climate it is the fresh and flowery herbage, the poplar, the willow, which seek the beneficent water, and plant their roots in the moist soil. In Africa the graceful foliage of the palm-trees shadows the surface of rivers, as in the celebrated valley of the Nile, while the gigantic baobab darkens the watercourse of the Zambesi and other rivers. In tropical regions a luxuriant and entangled vegetation covers the banks; the trees raise their lofty trunks from amidst a confused mass of vegetable growths, their foliage towering high above tufted shrubs and water-plants with gigantic leaves; creepers, twining in the midst of this living labyrinth, form a thousand graceful garlands. The decayed trunks cannot sink to earth, for the multitude of plants form such a compact mass, that the trunks are supported by a thousand connections to the living trees. The fecundity of Nature appears in all its power in this exuberant vegetation which covers the ground.

This massing and entangling of the vegetation causes in American rivers a remarkable phenomenon produced by an accumulation of floating trees called *rafts*. The trees, uprooted by the force of the wind or by land-slips, are drawn along by the current, arrested in their course by islands, shoals, and other obstacles, and thus form moving islands, which stretching across the surface of the river, offer formidable impediments to navigation. Among the larger

FIG. 14.—FORMATION OF FLOATING ISLANDS ON THE MISSOURI.

rafts or floating islands, we may mention those of a branch of the Mississipi, the Afchafalaya, which constantly bears along with the current a large quantity of wood brought from the North. During the last forty years this river has amassed such a quantity of floating débris in one spot, that an enormous island has been formed, 7 miles in length, 720 feet in breadth, and 8 feet in depth. In 1816 this mass sank and rose again with the level of the river, which circumstance did not at all retard the growth of vegetation, as the island was covered with a mantle of verdure. In the autumn it was gay with flowers. In 1835 the trees of the floating island had attained a height of 60 feet, and the state of Louisiana ought to take measures for the destruction of this immense raft, presenting as it does an insurmountable obstacle to navigation.

On the banks of the Red River, the Mississipi, and the Missouri the traveller often encounters masses of the same kind; the courses of these rivers are, like that of the Afchafalaya, impeded by the heaps of uprooted trees and the too abundant remains of wrecks (Fig. 14). United by the creeping plants, and cemented by the slime of the river, this débris forms in time floating islands. Young shrubs take root on them; serpents, caymans, birds come to make their homes amidst these verdant masses, which sometimes float down as far as the sea. But occasionally a large tree becomes caught in some sand-bank, and is there fixed; it extends its branches like so many hooks, from the grasp of which the floating islands cannot always disengage themselves. One tree is often sufficient to impede the progress of a thousand others, and in the course of years these spoils from far-off parts accumulate, and sometimes even change the entire course of the river.

The Colour of River Water.

Nature seems to take delight in tingeing the waters of the Orinoco and other American rivers with shades of every hue; some are blue, some green, some yellow, some are brown as coffee, some nearly as black as ink. The waters of the Atabapo, and those of Temi, Tuamini, and of Guiana, have the brown tint of chocolate. Under the shade of the palm-trees these rivers assume a black hue, while imprisoned in a transparent vase they appear of a golden yellow. The intensity of the colour is due, no doubt, to the presence of organic matter. When the sun has disappeared below the horizon, the Orinoco reflects the moon and the constellations with admirable clearness (Fig. 15).

The waters of the Orinoco, like those of the Nile and many other rivers of Africa and Asia, have tinged with a black hue the shores and granite blocks which they have for so many centuries been laving; from this it follows that the colouring of rocks and stones, which rise amphitheatre-like above their shores, is valuable evidence of the former level of the rivers. On the banks of the Orinoco, among the rocks of Keri, at the mouth of Jao, are to be seen cavities painted black by the action of the river, although these cavities are situated more than sixty feet above the present level of the waters. Their existence demonstrates to us a fact already proved from observations made on the beds of European rivers—namely, that those currents, of which the greatness strikes us with astonishment, are merely the humble remains of gigantic bodies of water which traversed our continents in the geological era, before the birthday of mankind.

FIG. 15.—VIEW ON THE ORINOCO BY NIGHT.

Subterranean Circulation.

The torrents of rain which the clouds pour upon the surface of the globe, do not all return to the sea by following the tracks traced out for them on the surface by the courses of streams and the beds of rivers. A vast body of liquid penetrates into the bosom of the ground, percolates into the sand and clay, becomes absorbed by the porous rocks, and descends, according to the law of gravity, until it finds its subterranean voyage stopped by impermeable strata. A natural drainage is thus at work on the surface of the earth; and the waters are to be found accumulated in vast unknown reservoirs, having escaped from the fluvial arteries, the vast and numberless ramifications of the great superficial hydraulic system. Streams, watercourses, even rivers sometimes disappear into the soil, and are lost in profound and unexplored abysses. The Guadiana becomes lost in a flat country in the midst of an immense plain, and afterwards reappears on the surface of the earth, after having traversed the subterranean arch of a natural bridge, where, to use the Spanish phrase, a hundred thousand horned cattle could find pasture. The Meuse loses itself at Bazeilles. The Drôme, in Normandy, disappears suddenly in the midst of a plain, through a hole thirty-three feet in diameter. These examples might be greatly multiplied, and it would also be easy to cite several other rivers, such as the Rhone, of which the loss is merely partial. According to Pliny, the Alpheus, in the Peloponnesus, the Tigris in Mesopotamia, and the Timavus in the territory of Aquileja, perform the most mysterious journeys when buried in the earth.

The most remarkable instance which can be produced of the penetration of water into the earth, is in connection with a lake varying in its level, which is to be seen at Kirknitz, in Carinola. The lake extends in winter over a surface of two leagues in length and one in breadth; towards the middle of summer, when the sun pierces the earth with his burning rays, the level of the water sinks rapidly, and in three or four weeks the bed is completely dry. The water has escaped by means of fissures, which can at that time be distinctly seen, and has filled the numerous subterranean cavities of the surrounding mountains. The peasants are in the habit of cultivating the soil laid bare by the retreat of the waters. When the harvest has been gathered, and the soil of the lake has rewarded the husbandman's toil by a rich and abundant crop, the water returns by the same route and inundates the valley, bringing with the stream the fish that have accompanied its subterranean wanderings. Kirknitz is, in fact, a true subterranean lake, which migrates like the swallows. In summer it plunges into the bowels of the earth, and in winter covers the surface of the earth.

Intermittent lakes of the same nature are to be found in France and various other countries. "Near Sable, in Anjou," says Arago, "there existed, in 1741, a spring, or, to speak more correctly, a pit, from 20 to 26 feet in diameter, usually known by the name of the Bottomless Fountain. This fountain frequently overflowed, bringing with it a great quantity of fish. There is, therefore, ground for supposing that this locality formed the vent of a subterranean lake."

The upper layers of stratified soils are often penetrated with layers of water, placed at various depths. This is the case at St. Nicholas d'Aliermont, near Dieppe, where as many as seven water-bearing strata are interposed, the beds being separated by impermeable strata.

In 1831, when an artesian well was completed at Tours, there was taken from the depths of the earth clear water, which contained branches of thorny shrubs, marsh-plants, and grain, in a state of perfect preservation, a fact proving decisively that they could not have remained any length of time beneath the water. These reservoirs cannot be merely the result of infiltrations, for they have been found to carry along with them morsels of wood and shells, which could not have passed through the pores of a natural filter.

The celebrated fountain of Nismes, of which the mean discharge is 286 gallons of water a second, has often been seen pouring forth from 2,200 to 2,640 gallons in the same time, after violent rains have occurred in that neighbourhood. It has been observed that the exceptional discharge occurred soon after heavy rains which had fallen some distance off, a fact which proves that water can rapidly traverse great distances through subterranean arteries.

By penetrating into the fissures of the soil, water sometimes becomes heated; the temperature thus attained is often a very high one, so that the water reappears on the surface of the earth in a boiling condition. Thermal springs of every description originate in this way, the temperature of the water having been raised by subterranean wanderings. The heated waters dissolve substances from the rocks which they encounter in their passage, and form mineral springs, often of great value, from their medicinal qualities.

Iceland produces wonderful natural fountains of boiling water, which are known by the name of geysers. Every half hour, a heavy and indistinct sound announces the bubbling up of the boiling liquid. The water bursts from the ground with a loud noise, and rises in an immense column 150 feet high. Presently the column of water vibrates, falls back upon itself, and disappears in the mysterious underground passages from whence it came. New Zealand, in the same manner, presents very striking instances of boiling springs. All round Lake Roto Mahana there rises from every depression of the ground a thick volume of vapour, and more than two hundred geysers issue from the east side of the boiling lake. The most remarkable of these boiling mouths is the Te-Ta-Rata (Fig. 16), which is the principal vent of the mass of water which has become heated by contact with the internal heat of our globe. "The enormous column of water," says Ferdinand von Hochstetter, in his travels, "rises up in a boiling state to a height of from 100 to 115 feet, and fills an oval basin 262 feet in circumference, bordered round its edges by a snow-white drapery of stalactites."

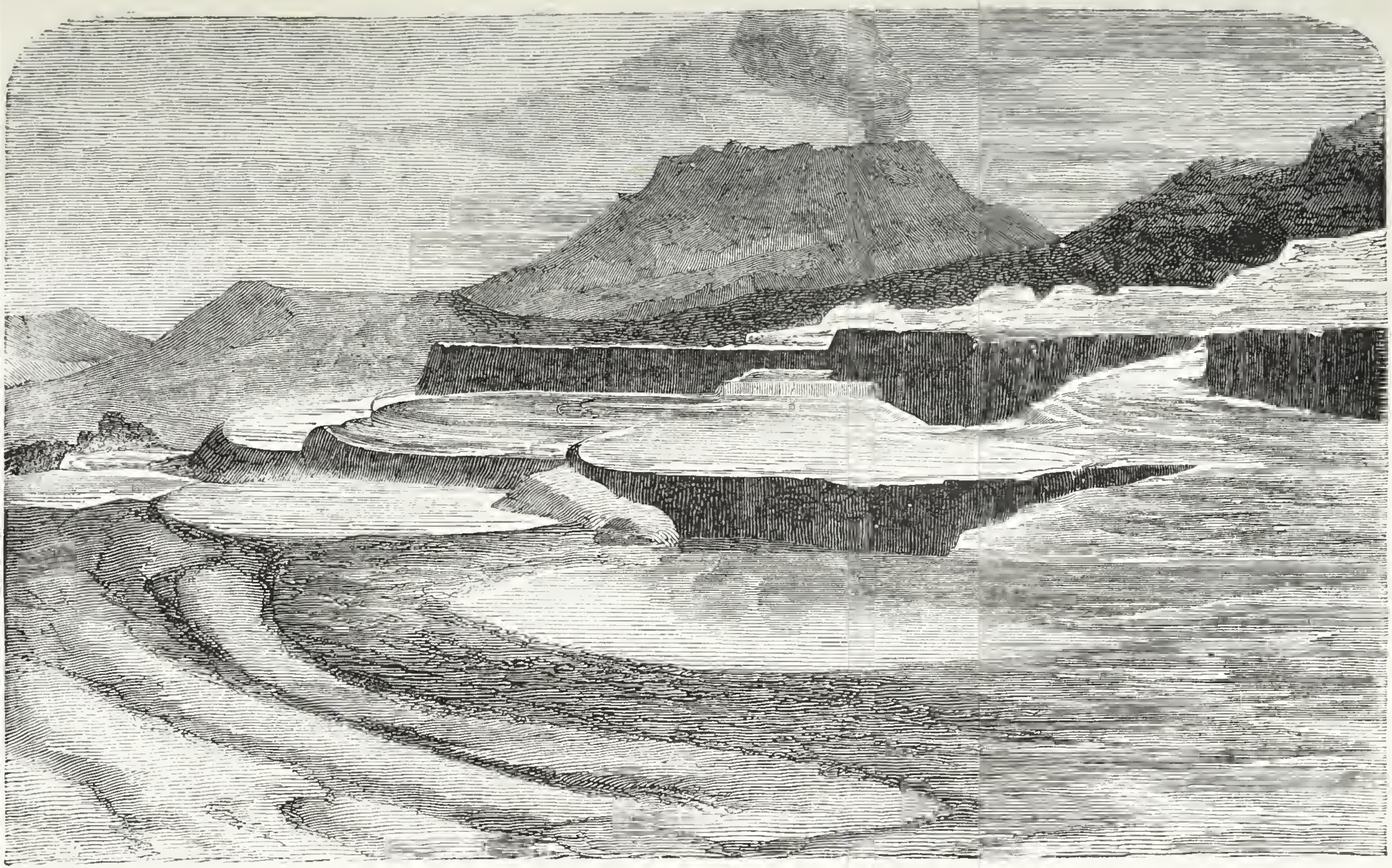

FIG. 16.—TE-TA-RATA, NEW ZEALAND.

BOOK III.

THE ACTION OF WATER ON CONTINENTS.

CHAPTER I.

MECHANICAL AND PHYSICAL ACTION.

IN traversing the earth, in the beds of rivers, the basins of lakes, and through subterranean channels, the waters are for ever accomplishing works grand and numerous. One of the most important elements of destruction resides in the power which water possesses of dilating by congelation. The liquid penetrates through the fissures of the hardest and most compact rocks, and ultimately succeeds in breaking them by the mechanical force which it develops in solidifying; enormous blocks of stone are thus detached from the mountain-sides, as if a powerful and irresistible lever had raised them for the mere purpose of precipitating them into the valley beneath.

Another property of water plays also an important part in the modifications of the globe. Water eats away the soil which it moistens by gradually carrying away the earthy matter; it penetrates through all fissures, carries away from the earthy particles the natural cement which binds them together, and in that way produces landslips, which are sometimes the cause of very serious disasters. The power water possesses of transporting solid materials is very remarkable; the earthy matter is drifted along by the running water which bears it, stones, and even rocks being sometimes carried to a distance. The friction of the fragments borne along by the torrents operates gradually like a rasp. It is capable of wearing away in time the hardest substances in Nature, and of producing enormous excavations in the mountains and ravines (Fig. 17). These multiform actions are often carried on simultaneously, but in order to study them it is necessary to examine each property separately.

The Currents—Transport.

We may well find matter of astonishment in the facility with which currents, often by no means rapid, transport heavy sand and gravel. But it must be remembered that the weight of a rock in the water is not the same as in the air. Every swimmer has noticed how much lighter he feels when his body is plunged in water. Archimedes made the same observation long ago, and it led him to the discovery of one of the most important principles in hydrostatics.

Whenever a body is plunged in water it loses a part of its weight, equal to the weight of the volume of water which is displaced, and as the density of a great number of stones is not more than double that of the water, it follows that substances drifted along by a current have generally lost half of what we term their weight. The waters of the majority of rivers do not flow with any very great rapidity, whereas the quantity of earthy material which they carry is

FIG. 17.—RAVINE OF OCCOBAMBA.

enormous. The acceleration of the speed of rivers depends on the incline, more or less rapid, over which they flow. It has been ascertained that the waters of the Po hold in suspension $\frac{1}{160}$ of their own weight in solid matter, those of the Rhine $\frac{1}{100}$, those of the Yellow River $\frac{1}{200}$.

From the calculations of Major Rennel, it has been ascertained that the Ganges casts into the sea, at the time when it is at the highest flood, a mass of water weighing 2,805 tons a second. The total mass of deposit drifted down by the Ganges into the sea during the space of one year would, according to Sir Charles Lyell, exceed in weight forty-two of the great pyramids of Egypt, and that which is carried down in four months, at the time the river is swollen, would be equal to forty pyramids. The mind has no faculties adequate to the conception of the grand scale in which the river Ganges effects such a transport. Looking upon the slow course of this powerful body of water, watching it traverse majestically the alluvial plain which it furrows, it would be difficult to realise the mighty work which the stream accomplishes. What efforts would be necessary on the part of man before he could effect such a transport. A vast fleet would not transport from the upper basin of the Ganges to its mouth a mass of materials equal to what the great river so easily carries itself during the four months when it is flooded. To these labours of the Ganges are added those of all other rivers, and thus we have in water a Titanic labourer who never ceases to tear from our continents the earthy materials of which they are formed, and to bear them far away into the domains of ocean.

The rivers do not alone drift away mud and clay, but they carry in their waters various mineral substances, which they hold in solution. The water which falls upon the earth dissolves some constituents of the rocks and stones which meet it in its course. Thus the pure water from the clouds returns charged with salts to the sea. The result is a constant accumulation of soluble materials *in* the sea, and probably a slow augmentation of saltness. The zoophytes and mollusks are nourished by the carbonate of lime which the fresh water by its circuit has carried into their domains, and thus transform into corals and shells the banks of chalk which formerly covered our continents. Is not that spectacle a grand one which is offered us by nature in the sublime simplicity of the means which she employs? The water of the clouds charged with the carbonic acid of the air, falls upon our limestone hills, it becomes charged with carbonate of lime, which it pours into the bosom of the rivers. Carried onwards into the ocean, the carbonate of lime is drawn into the regular currents, and seized by microscopic animals, thus adding one more stone to the new empires which are being gradually prepared for future generations.

Torrents and Rapids.

When water glides down a steep declivity its power of transport is wonderfully augmented, and enormous rocks can then be borne away. Along the sides of mountains the streams precipitate themselves with extreme violence; they chase before them blocks of stone frequently not less than a cubic yard in bulk (Fig. 18). Thus it happens that rocks whose first home was on the summits of mountains, came to be transported into the valley, and further on into the adjacent plains. Ultimately they reach the sea, there to be reduced to sand or mud. Among the sand scattered so plentifully over the shores of the North, among the millions of silicious particles broken and polished in the bosom of the wave,

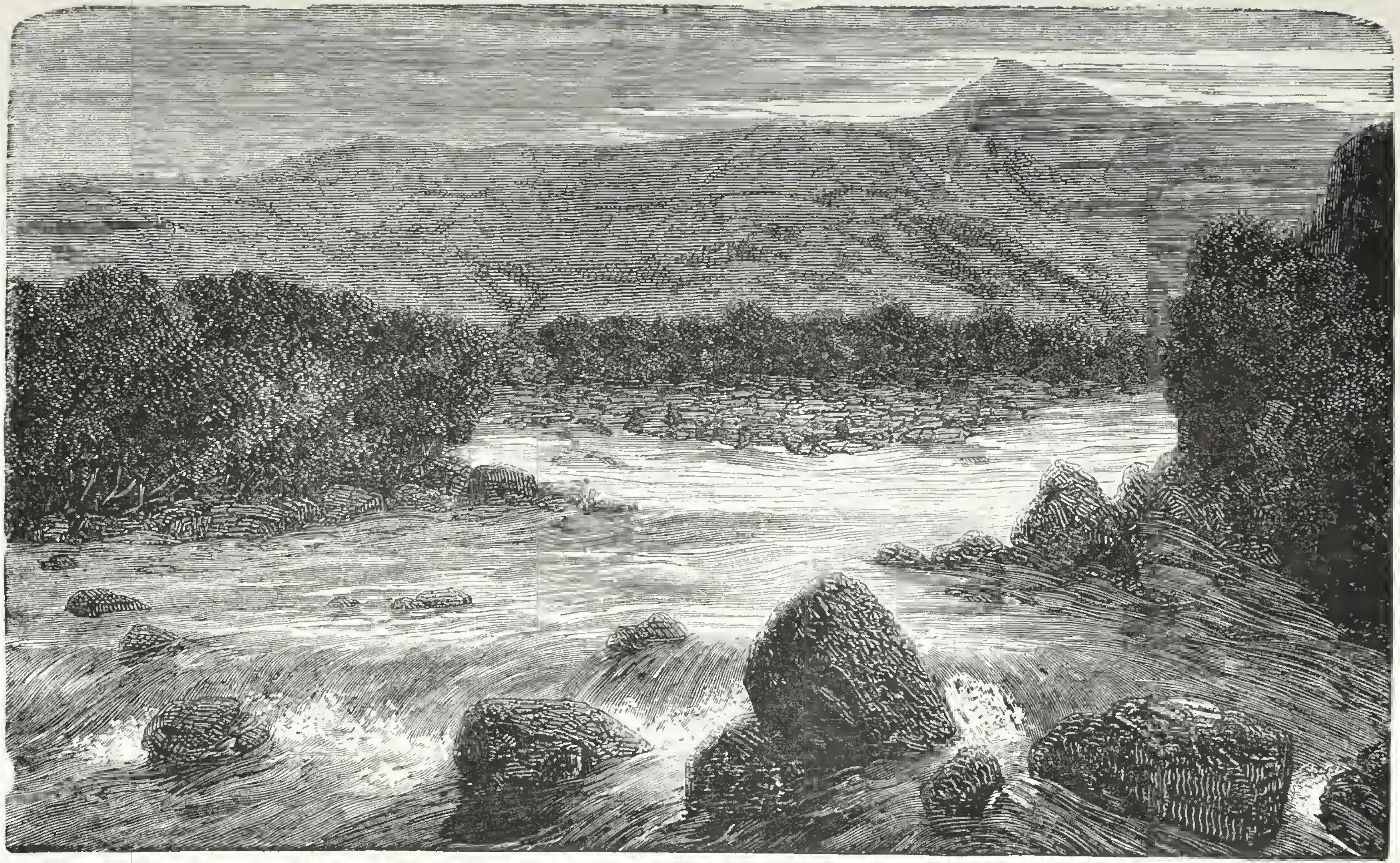

FIG. 18.—JUNCTION OF THE RIVERS YANATILI AND QUILLABAMBA IN PERU.

there is perhaps here and there a grain from fragments which have escaped from the summit of the Alps!

In the new world, the larger rivers, traversing an uneven soil, often precipitate themselves down inclined plains with an astonishing rapidity. These rapids do not always hinder navigation, and the American Indians venture in their light craft along these terrific currents. The rapids of Montmorency, in Canada, thus suffer the canoes of the natives to glide upon their bosom.

In 1835, after the landslip of the Dent du Midi, in the Alps, an enormous mass of earthy débris formed a black and compact mud, which did not contain one-tenth part of water; notwithstanding which it flowed down into the Rhone, and transported large blocks of stone into the bosom of the river, causing it to overflow the opposite bank.

The celebrated mud torrents of Peru and Java have often been described by travellers; they glide down declivities, and cover entire countries with an immense mantle of clay.

Floating Ice.

In those countries in which the cold in winter is sufficiently intense to convert the surfaces of rivers into ice, the power of transport possessed, as we have shown, by all running water, is considerably augmented.

In 1821, M. Lariviere, being present at the breaking up of the ice at Niemen, on the Baltic, saw a floating block of ice, 30 feet in length, descending the current of the river and running aground on the bank. In the middle of the mass of solid water a block of granite more than a yard in diameter was discovered. This stone, analogous to the red granite of Finland, had been transported in a raft of ice.

All floating ice is mingled with pebbles and small fragments of stone, which, imprisoned in a frozen envelope at the moment of its formation, are carried along until a higher temperature releases them, by melting the mould in which they are contained.

Waterfalls and Cascades.

The cascades in the rivers of Europe and Asia, and all countries, afford us, beyond any other work of Nature, a spectacle of the effects of water in modifying by its inroads the shape of continents. In America, the Niagara escapes from Lake Erie, cuts its way through the soil with great velocity, and, after a passage through tremendous rapids, precipitates itself into an immense abyss, in order to join Lake Ontario. An island, which is situated on the edge of the cascade, divides it into two distinct sheets of water, one producing the Horseshoe, and the other the American Fall (Fig. 19). The waves, rushing on to the falls, roll over a bed of hard limestone, disposed in horizontal strata over a bank of soft clay. The limestone rock juts out 39 feet above the open space, and forms a threatening projection, an enormous protuberance, which appears every instant on the point of tumbling into the gulf beneath. The lower bed of clay is incessantly undermined by the clouds of spray rising from the basin into which the cascade falls, and striking its earthy walls with violence continually wear them away. The limestone bed, thus deprived of its support, becomes separated into fragments, which occasionally fall into the lower basin, and cause by their fall a shock which is sometimes felt at a great distance, and echoes through the air like a clap of distant thunder.

FIG. 19.—THE FALLS OF NIAGARA.

When the river has passed the Falls, it rolls its hoarsely-roaring waves over the bottom of a valley, which it has scooped by its rapid motion,—a valley the walls of which the river is perpetually elevating by excavating the horizontal strata which form its bottom. On the bed of the river are heaped rocks, tossed promiscuously one upon another; the shores bristle with jagged cliffs. These heaped up fragments,—these rocks, which came perhaps originally from some far-distant country, form a marvellous combination of all that is wild and confused, proving how these materials have been torn and dragged by a gigantic force from the soil which gave them birth. This force is none other than that of water.

The destruction of the edge over which rushes the Falls of Niagara, produced by the gradual wearing away of the limestone rocks, has caused the Falls to move backwards. In 1829, Mr. Bakewell ascertained that the Canadian Fall was at a distance of between 130 to 160 feet from the spot which it had occupied fifty years before. If the retrograde movement of the Falls had been always accomplished with the same velocity, the ravine into which they precipitate themselves, and of which the length is about six miles, would have been formed in 10,000 years. In order, however, for such calculations to be exact, it would be necessary to understand the original topography of the country. The action which takes place under our own eyes may be widely different from that which took place centuries ago.

Nor is it less difficult to arrive at probable suppositions as to the future retrogression of the great cataract. In proportion as it moves further from the place where it escapes at present, the height of the precipice may augment or diminish, in consequence of various modifying causes. If, in the course of years, the Falls of Niagara reach Lake Erie, the Lake probably will be drained rapidly, for its greatest depth does not exceed the height of the cascade. The mean depth of Lake Erie is at present said to be only about 65 feet.

Tourists and travellers may thus be to some extent deprived of one of the most beautiful spectacles which Nature can offer them amidst all the effects, varied, changing, picturesque, and majestic, which she produces by means of the liquid element.

The Zambesi is also a striking example of excavations deepened by the action of water. This great African river plunges into a vast abyss, which it is incessantly making deeper, and its fall produces clouds of froth and vapour, which rise into the air in gigantic columns (Fig. 20). Picture to yourself a river a mile broad, which finding itself without a bed, falls into a deep and narrow ravine. The waters confined within this gulf boil up with so much energy that five vast pillars, called by the negroes who dwell upon its shores "the smoke that thunders," rise up towards heaven in columns which yield to the least breath of the wind. While dark at their base, at their summit they resemble the smoke of a vast furnace. The bed along which the Zambesi flows is a cleft in a vast mass of basalt. This fissure is continued on the other side of the Falls, and forms a long zigzag furrow, in which the water eddies and rebounds with great force, part of its side being carved and striated by the ever-moving fluid which wears and polishes them unceasingly.

But it is especially around the Falls of Félou (Fig. 22) that the most beautiful and sculpture-like effects of fresh

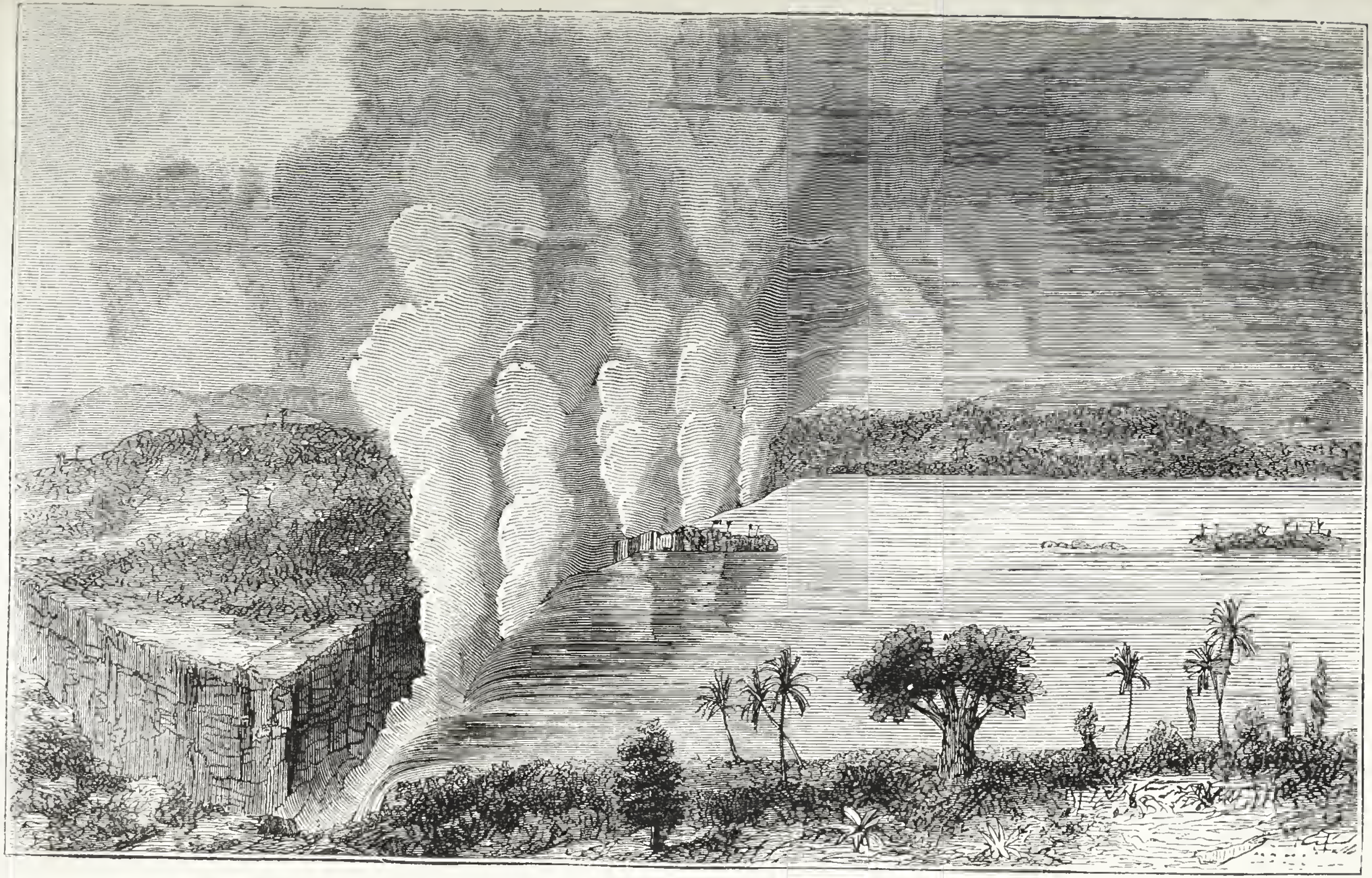

FIG. 20.—FALLS OF THE ZAMBESI.

water acting on a rocky substance can be seen. The waters put in motion pebbles of red quartz, which they meet with in their course, and the solid rocks, worn away as by the drill or the chisel, is marvellously excavated into caverns. At the time of year when the waters are low we find in these caverns piles of pebbles, which reveal the implements by which the caverns have been formed.

It is not, however, necessary to travel so far in order to

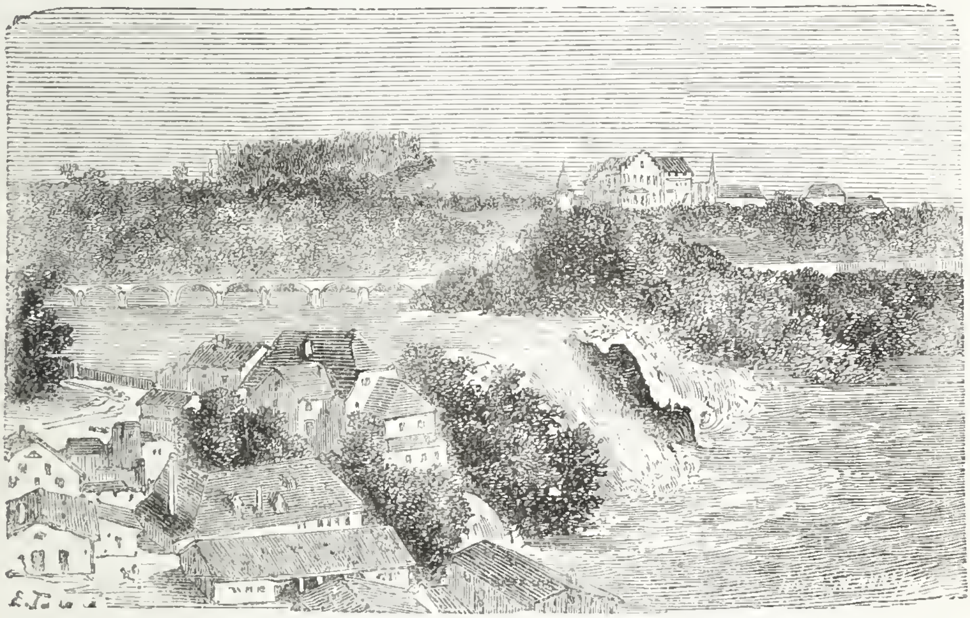

FIG. 21.—FALLS OF SCHAFFHAUSEN.

admire the spectacle of waterfalls and cascades; Switzerland and the Pyrenees both abound in similar marvels. Who has not heard of the beauties of the Falls of the Rhine near Schaffhausen (Fig. 21); and can there be anything more imposing, more sublime, than the ten or twelve torrents which are hurled from the heights of Gavarnie? Imagine a semicircular area enclosed by a wall 1,200 feet high, surmounted with a snowy ridge, a series of battlements formed by glaciers which give birth to numerous torrents. The most considerable of the Falls of Gavarnie rushes through a height of 461 yards. It falls gently as a descending cloud, or as a muslin veil which is being spread out; the air breaks its fall, the eye finds pleasure in following the graceful undulations of this beautiful aerial veil. The sun shines through the feathery waters with the softest and most agreeable lustre. The cascade reaches the bottom in a form resembling a plume of light and softly-waving feathers, and rises up again in a dense silvery dust. The air is motionless, no living creature exists in the solitude. Nothing is to be heard but the monotonous murmur of the cascades, which resembles the rustling of the leaves in a forest agitated by the wind.

FIG. 22.—FALLS OF FÉLOU.

CHAPTER II.

DELTAS.

AFTER the melting of the snows, or after a violent storm, the rivers often become greatly increased in bulk; they overflow their banks, they expand into the valleys, where they spread out a large liquid sheet, which deposits a thick layer of mud. If the waters find a temporary home in the bosom of lakes they abandon these earthy substances, which the current had borne in its rapid course and thus deposit at the bottom of the lake a layer of greater or less thickness. But when rivers thus charged with mud reach the sea, and when the rapidity which has held the particles of clay in suspension has ceased, these particles are deposited in the vicinity of the river's mouth, thus forming at last new ground, which extends the coast; and if the coast be one on which the waves cast up much sand, and thus contributes to the extension, it may create in time provinces and entire kingdoms.

The mud which rivers carry is thus deposited either in lakes, or at the mouths of those rivers which discharge into the ocean, and thus gives birth to those encroachments which are called Deltas.

The alluvial soil which is formed at the mouth of the Rhone, towards the upper end of the Lake of Geneva, affords a striking instance of the thickness which can be acquired by superposed layers of mud in a short space of time. The village of Port-Valais, which stood eight centuries ago on the very edge of the Swiss lake, is now actually separated from it by a tongue of land upwards of a mile long. The sand and mud deposited by the waters have formed this new land, and we can find a great number of smaller deltas on the banks of the Lake of Geneva which are perpetually invading the dominions of the blue and transparent water.

Lake Superior, in America, the largest lake in the world, which covers an area almost equal to that of France, receives into its bosom considerable quantities of earthy substances, of sediment regularly deposited in thick layers. Like the other lakes of Canada, Lake Superior offers upon its shores indications precious to science, which show the work effected by these waters in ancient times, and from them we learn that the waters attained formerly a very high level. A long way from the present shores we meet with parallel beds of pebbles and banks of shells, which form one above another superincumbent layers, resembling the steps of an amphitheatre. These beds of pebbles arranged by the waters, these collections of shells brought together by the movements of the waves, sometimes rise to a considerable height, and can be seen upon ground situated more than 49 feet above the present level.

The majority of rivers form at their mouths deltas larger or smaller, which encroach upon the domain of Ocean. The account which Strabo has given us of the delta of the Rhone in the Mediterranean, does not agree with the present configuration, a fact which indicates the alterations which have taken place since the age of Augustus. The increase of this delta during the last ten centuries is in other ways measurable, owing to the existence of ancient structures, which afford definite information. Far distant from the present coast are to be seen many lines of towers and nautical signals which were certainly raised on the very shore of the sea. The peninsula of Mega, described by Pomponius Mela, is now inland, far from the shores of the Mediterranean. The Tower of Tignaux, built on the coast in 1737, is now about one mile inland.

The Adriatic Sea presents a combination of all the circumstances which are most favourable to the formation of delta. A gulf which penetrates deeply into the land from a sea without either tide or currents, receiving the Po, the Adige, and numerous other rivers, is well adapted to exhibit the formation of land by that power of transport possessed by fresh water. All the rivers are incessantly making up mighty banks of mud and sand, torn from the lands through which they have passed. Adria, which in the time of Augustus was able to receive Roman galleys into its port, has now become an inland town surrounded by fields, situated at a distance of eight leagues from the coast. The town of Spina, built at the mouth of a large arm of the Po, is now four leagues inland.

The Po, in drifting down to its mouth enormous volumes of mud and fine sand, is constantly invading the sea, which, having no tide, is unable to offer any obstacle to the intrusions of the river. The neighbouring countries are exposed to extensive modifications, and we need only cite the example of the river Isonzo, which has gradually abandoned its bed, having been driven thence by alluvial deposits.

This stream now runs in a direction above a league to the west of its ancient channel, and in the neighbourhood of Ronchi a Roman bridge has been found buried beneath the deposits of the river.

Instead of abandoning and deserting their ancient bed, some rivers gradually raise their level above that of the soil, by covering the land over which they glide with their deposits of alluvium. The Mississipi and the Nile afford examples of rivers which have thus raised the level of their bed. The banks of the Nile are much higher than the surrounding plains; so much so, that during the inundations, when the waters rise and overrun the neighbouring countries, the banks are very seldom completely covered by the waters. The Nile, which, like the majority of great rivers, is subject, from the action of atmospheric variations, to periodical floods, spreads its waters, in consequence of the gradual elevation of its bed, over spaces more and more considerable; and the alluvium gains more and more every year upon the sand of the desert. Antique temples and statues, which thirty centuries ago overshadowed the waters, are now disappearing under a thick layer of alluvium. The priests of Egypt were correct in terming their country "a gift from Heaven," since it owes its fecundity to the generous river which fertilises the soil.

In consequence of the Nile depositing its sediment over the land, it does not rapidly increase the great delta situated at its mouth, although some mouths of the Nile mentioned by ancient geographers are now completely closed by deposit. "The distance from the Island of Pharos to Egypt," says Homer, "is that which a vessel can accomplish in a day with a favourable wind." At the present day a swimmer can in a few strokes reach the island.

When rivers, instead of pouring their waters into the inland seas, discharge into the ocean, they become subjected to the influence of tides, and the deltas are in consequence less rapid in formation. The tidal currents have a severe struggle to sustain with those of the river, and often instead of the land making an inroad upon the sea, it is the salt water which penetrates into the mouth of a fresh-water river. The ocean thus intrudes itself into the continent where it forms a gulf, an estuary, a *negative delta*. But when the volume of the river is considerable, and when the velocity of its waters is great, the action of tides can be neutralised, and the continental artery succeeds in constructing its delta in spite of the wrath of the waves. At the mouth of the Ganges the sea is invaded by a tongue of land eighty leagues in length and seventy-two in breadth. The margin of this vast delta is indented by an infinity of small rivers, by a labyrinth of salt water, which extends over a vast space called "the Sunderbunds;" a veritable desert, in which the tiger and alligator reign as masters over an area equal to that of Wales. When the waters of the river are low, the tide exercises its influences, but when the stream has become swollen by tropical rain, the waters rush forward with tremendous impetuosity; they are then capable of resisting the oscillations of the sea, repulsing the mighty element. The Delta thus increases rapidly in a short space of time, and encroaches upon the empire of the sea. During the other seasons of the year the waves take their revenge.

CHAPTER III.

INUNDATIONS.

RAIN, and the torrents which are its consequence; avalanches, and the overflowings of rivers which result from them; earthquakes, which drive entire lakes from their beds; glaciers, which form the temporary prisons of a mass of water, to which they open a sudden passage by liquefaction, are the principal causes of inundations.

In 1826 the White Mountains, in New Hampshire, were (after two years of drought) inundated by torrents of rain. The torrents thus formed flowing rapidly down the sides of the mountains, rolled large stones towards the banks of the river Saco; their speed becoming accelerated from second to second, it was not long before they swept along with them trees and masses of earth. One of these moving masses, not measuring less than 100 yards in length, precipitated itself into the bed of the Saco and produced a partial overflow, the stream being swollen under the influence of the rain. In a few hours several valleys were completely inundated, and from all parts violent torrents rushed precipitately, carrying down with them from the hills uprooted forests of trees, torn from the earth like stalks of wheat beneath the sickle of the reaper. The rivers Saco and Amonoosuck completely overflowed their banks, burst forth from their channels, and deluged the surrounding plains; so much so that in a short time whole square leagues of neighbouring country presented a terrible scene of devastation. In 1818 the Val-de-Bagnes became converted into an immense lake, owing to the stopping up of some defiles, caused by avalanches of snow. This lake was confined by hills of ice, and by embankments of snow which melted in the spring, and the valley, so full of water, became empty in less than half an hour. The waters thus set free rushed in prodigious volume, and precipitating themselves with a speed of twelve yards a second, they inundated to a great distance the adjacent country, carrying with them houses, trees, rocks, and ploughed soil.

The list of such disasters is unhappily but too long, and examples of the same description may be infinitely multiplied. In these catastrophes water oversweeps without pity the productions of Nature equally with human handiwork, and reveals itself, as the strongest and most terrible of all the elements.

The Rhone, the Loire, and indeed all rivers, are frequently liable to floods, of which we know but too well the melancholy consequences; and how to prevent the return of such fatal occurrences has long been felt as a necessity.

Some rivers have in modern times become subject to sudden floods, so as occasionally to overflow their banks, burst all barriers, and deluge surrounding countries; while others have become choked with sand, and even their sources have dried up. What has caused these changes in the hydraulic system? Walk through forests that are being cleared, and look at the trees on the mountain-side which are falling under the wood-cutter's axe, and there you will learn one cause of such changes. It is not in France that the effects of clearing woods are manifest; in order to see them we must transport ourselves to America, where natural phenomena are on such a magnificent scale.

In the year 1800, Humboldt sought near the town of Neuva Valencia for the lake of Valencia, of which he had met with numerous descriptions in the works of old writers. The lake of which so much had been said was nothing more than a pool. To this fact we may add the explanatory one, that during the last two centuries numerous clearings have taken place in the neighbourhood. Twenty-five years later, M. Boussingault visited these regions, and the lake seemed to have regained its former size; but five-and-twenty years of neglected cultivation, the result of civil war, had enabled the neighbouring forests to shelter the ground under their thick branches. In Ascension Island the same phenomenon has been observed. A mountain was cleared of its wood, and in consequence an abundant spring in the vicinity dried up. Later, however, the spring reappeared with the trees, which had been permitted to grow again. In other regions the devastation of forests is followed by frequent inundations, while where the trees are preserved the system of waters remains unaltered. On the road to Quito, for instance, is to be seen the Lake of St. Pablo. From the period of the first invasion of Peru the country has remained the same, the trees have been protected, and the lake has not varied.

These facts prove that great clearings favour the evaporation of the water from the ground, and thus sometimes cause the drying up of lakes and of watercourses. When, on the contrary, countries are planted with trees, the rain-water remains on the surface of the earth. If the trees are cut down, torrents during the heavy rains will glide down the declivities of the mountains, and not meeting with any obstacle, cause the rivers to overflow. The leaves of the trees during the night condense the vapours of the atmosphere, they deprive the air of its moisture, and render the rain less violent. Thus the forests affect the distribution of rain, prevent the soil from being worn away by the action of water, and keep the rivers from becoming choked with sand.

But, it will be said, is it not possible to ascertain whether, since deluges have already occurred, we may not expect them again? Can science tell us whether we are still exposed to the encroachments of the seas which might result from an earthquake? Before answering this question it is necessary to know whether the revolutions on the earth's surface have been sudden or gradual; this is an important question, which has been the subject of eager discussion between distinguished scientific men. It is probable that both hypotheses are true; in our own days the shores of certain continents are rising gradually; and in the course of ages the cumulated effects become the cause of highly important modifications on the earth's surface. On the other hand, the uprising of mountains and the shocks of earthquakes have effected changes both sudden and terrible. When the chain of the Cordilleras first formed an immense ridge on the surface of the globe, the earth must have been violently shaken, and the sea, tossed in its bed, probably produced vast deluges.

Will such violent phenomena recur again? Probably not; for the crust of the earth, augmenting in thickness in proportion as the globe grows colder, will oppose a resistance ever stronger and stronger to the subterranean fires.

It is possible that our planet is destined to lose its oceans and its atmosphere, and to pass gradually into a condition similar to that of the moon, for the waters become absorbed in proportion as new rocks are formed by the consolidation of the molten portions of the globe.

The solid parts of the earth are porous; and the water, insinuating itself by a thousand openings, travels slowly but surely towards the centre, and disappears in proportion as the crust increases in thickness. We have already seen that rivers and lakes have diminished in volume since the geologic ages. It may be that the dried-up earth will ultimately behold all life disappear from its surface; the air will no longer oppose any resistance to the passage of the solar rays; frigid nights will succeed burning days, though our planet will not the less continue its course around the sun.

CHAPTER IV.

CHEMICAL ACTION.

Petrifying Fountains—Stalactites.

THE effects produced by so-called petrifying fountains, have at all times attracted the attention of naturalists. Pliny tells us that at Peperina there is a fountain which petrifies all the earth which it waters; this is also the case with some hot springs at Delium. At Eurymenes the garlands which are cast into a certain fountain become petrified. At Colosse flows a river which turns bricks which are thrown into it into stone. In the mines of Scyros the trees which are moistened by certain waters become petrified, even to their branches.

The erroneous notion of the *changing of a body into stone* by contact with certain waters, has been handed down from one age to another, and even in our own days numbers of persons imagine that the so-called petrifying springs transform organic substances into stone.

The liquid charged with carbonate of lime deposits the salt which it holds in solution on the surface of organised bodies, animal or vegetable, and covers them with a solid layer, a chalky varnish which adapts itself to the external form of the object which it covers, but does not take the place of the material substance of which the object is composed. Thus organic substances become clothed in a solid envelope, and can be preserved for a long period in an unchanged form.

In France, near Clermont (Puy-de-Dome), at St. Alyre, at St. Nectaire, and in numerous other places, there exist springs and fountains which possess this incrusting property. Baskets of fruit, birds' nests, branches, and various other objects are placed in the water, and in a very short time become covered with a strong coating. The waters of Hieropolis, in Asia Minor, present one of the most beautiful phenomena to be met with anywhere in connection with incrustation; they run down the declivity of a mountain, and form there a series of fine petrified cascades.

Rain water charged with the carbonic acid from the air often traverses thick layers of calcareous soil, and dissolves the carbonate of lime by means of the carbonic acid which it holds in solution. Subjected to the effects of gravity the water sinks into the ground, and should it enter caverns or empty spaces, the carbonic acid will evaporate, and the limestone which the water holds in solution will be deposited in layers, to which nature delights in lending a thousand forms.

Natural caverns are thus very frequently furnished with stalactites, deposits conical in their form, resulting from the infiltration of mineral waters through the walls, and suspended vertically like the icicles we see upon the eaves of our houses in winter. The formation of stalactites remained long unexplained; philosophers were slow in tracing these apparent vegetations to the agency of water.

Stalactites are generally formed of carbonate of lime, but occasionally they are composed of silex or malachite. As, however, in all cases the method of formation is the same, we will confine our description to the carbonate of lime. This substance is insoluble in pure water, but dissolves in water charged with carbonic acid. Let us imagine that a water of this nature infiltrates into the earth and penetrates into the fissures of the rocks which form the walls of a grotto, or oozes through their porous texture. Some drops will remain for some time suspended. Such drops will evaporate, and leave the carbonate of lime which they have held in solution. The first drop will leave an almost imperceptible deposit of an annular form, the second will add to this deposit, and so will the others, until the incipient stalactite assumes a form similar to that of the quill of a feather, and the successive and continuous evaporation of other drops will at length close the orifice. The water will trickle along the sides of the tube, which increases externally, and as the deposits are more abundant towards the base than towards the extremity, in consequence of the progressive impoverishment of the fluid, the stalactite will ultimately present the appearance of a greatly elongated cone.

The water escaping from the upper portion of the vault, falls vertically upon the ground. When arrived there it evaporates and sets more of the lime at liberty; this is repeated by other drops, which thus form ultimately underneath the stalactite a deposit of the same nature, called a *stalagmite.* The stalagmites rising from beneath in time often reach the stalactites, which descend from above, and in this manner are formed the fantastic columns which decorate the interior of some grottoes. The fluid which trickles down the walls of these grottoes gives birth in the same way to deposits, of which the form bears a strong resemblance to those of draperies and waving folds, or to that of a cascade suddenly solidified.

In France, especially in the Pyrenees and in the neighbourhood of Besançon, there are several of these grottoes, in which water is incessantly employed in the construction of the most fantastic objects. The Grotto of Antiparos, in the Greek Archipelago, which has been visited and described by the celebrated naturalist Tournefort, is perhaps the most remarkable. After this may be ranked the "Trou du Han," in Belgium; the Grotto des Demoiselles, in Herault; those of Arcy, in Savoy; Kirkdale, in England; and Gaileureuth, in Bavaria.

The Grotto of Han is situated in the province of Namur. In this country the little river Lesse penetrates through a rocky cavity at the foot of an eminence, and disappears into the depths of a dark gulf with a deafening roar. The stream reappears at a distance of 1,300 yards. On the opposite side of the hill its waters, before so agitated, come forth as calm and limpid as if they had issued from a crystal fountain. What route have they traversed within the earth? If floating bodies are thrown into the Lesse on the side of the hill where it loses itself, they are never found on the other; and if the waters at their entrance are rendered turbid by a flood, an entire day elapses before their transparency is defiled at the exit. Beneath the rock where the Lesse escapes for the continuation of its course there reigns an intense gloom. A deep cavity has to be penetrated ere we can explore the wonders of this curious cavern. The Grotto of Han is composed of twenty-two different chambers, and numerous narrow and very long caverns. It is impossible without visiting them to have any idea how varied and striking a spectacle they afford.

After having traversed in succession the "White Hall," so termed from the brilliant layer of carbonate of lime which enamels its stalactites and rocks, the "Saltpetre Hall," the "Hall of Beetles," the "Hall of the Precipice," which contains a remarkable stalagmite resembling a balcony suspended over a deep gulf, the "Grotto of Antiparos," which derives its name from the resemblance which a limestone block in it bears to the famous "Tomb" in the Greek cavern, and lastly, the "Gallery of the Swallow," we reach the "Grande Rue," a narrow corridor 126 yards in length. The Grande Rue is a natural opening in a fine black marble, which is polished by the water that perpetually trickles over its surface. Finally we arrive at the "Mysterious Grottoes," in which the most astounding marvels of this vast cavern are crowded together. When a fire illuminates the groups of stalactites which hang from the dark and shadowy summit, where we see the alabaster stalagmites which cover the ground, the columns, fine and slender or massive and compact; the waving drapery gracefully festooned; the infinite number of translucent needles, of every length and thickness, which surround the vault; the concretions of every shape; strange ornaments of a fantastic style of architecture. We advance 500 feet further into the earth and reach the immense "Dome Hall," which is not less than 200 feet in length and 380 in breadth. We no longer see the stalactites, for the glare of the torches does not light the upper part of the vault, and the heights are lost in a thick gloom; but the stalagmites which strew the floor of the cavern are of colossal dimensions and of extraordinary shapes, seeming as if modelled and wrought by the hand of some skilful artist. Here we see an immense marble tomb, which is termed the Mausoleum; there lies a block of blackish limestone sparkling with crystals. A little further on, we come in sight of a fantastic swan, which hangs by its beak from the wall of the vault; of a tiara, which appears to deck the head of a giant; of a colossal throne, which is termed the "Throne of Pluto." All around are heaped up immense fragments of rock, polished and rounded by the action of water.

The silence of these sombre galleries is only disturbed by the falling of the drops of water which succeed one another in regular order, and which add some atoms of calcareous matter to the edifice which they are constructing. This sound, sharp and regular as that of the pendulum of a clock, is the sole indication of the work which the water carries on, and has been carrying on in these caverns during an incalculable series of ages.

Pisolites—Oolites.

Waters which hold solid matter in solution produce other concretions, termed by geologists "Pisolites" or "Oolites," according to the size and shape of their grains. These globular stones are formed in fountains, where the water containing the solid matter is in a state of violent agitation. The waters, by their motion, hold suspended numerous small particles of sand, which become centres about which the dissolved calcareous matter deposits itself; thus each particle is surrounded with a film which gradually increases, and in time becomes a thick envelope. As the grains increase in weight they sink to the bottom of the liquid; and being in contact with one another, they cohere and produce granular masses. We can observe the formation of similar rocks in the calcareous waters of Vichy; in those of Carlsbad, in Bohemia; and of Tivoli, near Rome.

Whereas pisolites only form very small concretions, oolites have often produced entire mountains. In such a case we can only form conjectures as to the origin of so singular a formation, which originated in the ancient geological epochs; it is, however, quite certain that here also the action of water has been busy.

Water charged with carbonic acid has also the power of dissolving limestone rocks, frequently producing thereby deep excavations; it is probable that the celebrated natural bridge of Ain el Liban has been produced in this way.

Still Waters.

After having examined the action of moving waters, let us take a glance at those vast marshes in which the liquid element is stagnant, and where it stretches inert and lifeless over the earth. Widely different is the work which water accomplishes, but not less important is the effect produced.

Organic substances, vegetable débris of all sorts, such as the remnants of reeds and other marsh plants, may be found decomposing in stagnant water; fermentation is thus produced in ponds and morasses where no current comes to renovate the waters, and noxious gases rise from the decomposing masses. Sometimes the remains of trees and plants become partially carbonised, and form at the bottom of the marsh deposits, which during the progress of ages are transformed into peat.

Such is a brief sketch of the effects produced on the surface of the earth by the labours of the waters. To recapitulate: water in its unwearying movement acts as a mechanical agent in diluting the soil which it moistens, in polishing stones, and in transporting mud, sand, and clay, in dilating itself by congelation, and in giving an impulse to the avalanches which cause rivers to overflow their boundaries and produce inundations. Water also acts chemically by dissolving rocks and minerals. The action of the water, as we have already observed, is destructive and reproductive. It carries away the earthy particles, only to deposit them elsewhere. The mountain feeds the delta. Water dissolves the limestone, and bears it down to the sea; but the water offers the limestone to the polyps, which seize upon it and build with it in the midst of ocean immense banks of coral. Thus existing lands furnish materials for future continents.

CHAPTER V.

YESTERDAY AND TO-MORROW.

"The world does not always present to us the same aspect; here where we are to-day treading the soil of a continent the sea has flowed and will one day flow again, the region where the sea flows now has once been and will again be a continent."—ARISTOTLE.

"AS I was one day passing through a very ancient and densely populated city, I asked one of its inhabitants if he could tell *when* it was founded." "It is," replied the man, "a great city, but to inform you how long it has existed would be absolutely impossible, and of that our ancestors were as ignorant as ourselves." Five centuries later I revisited the same spot, and perceiving no vestige of the town I inquired of a peasant who was gathering herbs on its site, how long a time had passed since its destruction. "By my faith," he replied, "you ask of me a strange question, this country has never been anything different to what it is now." "But was there not once a great city here?" I inquired. "Never," he replied, "as far as we can judge by what we have ourselves seen, nor have our fathers ever told us anything different." Another five centuries passed, and again I revisited the spot—this time the sea covered the site. Seeing some fishermen upon the shore, I asked them how long it had been since the sea had invaded this piece of ground?" "A man like yourself," said they, "ought not to ask such a question as that. This place always has been what it is now." Again at the end of another five hundred years I returned once more—the sea was no longer there, and I was desirous of knowing how many years had elapsed since the sea had retired. A man whom I accosted made answer, in reply to my question, as all the others had done; he said, "that things had always been just as I now saw them." Once more, after a similar lapse of years I returned for the last time, and found instead of the desert a flourishing city, richer, more populous, and more magnificent than the first which I had seen. Being desirous of ascertaining how long it had existed, I questioned the inhabitants on the subject, to which they replied, "The origin of our city is lost in the night of ages; we do not know when it first existed, and on this subject our fathers knew no more than we do." Thus speaks Khidhr, an allegorical personage introduced in the writings of a very ancient Arab writer, Mohammed Kazwîni, who flourished towards the end of the thirteenth century; and this graceful apologue sets forth in a manner both elegant and original the reciprocal changes of position which the continents and ocean have experienced.*

From a very remote antiquity philosophers have recognised that extensive modifications must have taken place on the surface of the globe, and the most ancient systems of Egypt and India have connected them with deluges. Among these

* The narrative which we have here been quoting is taken from a very valuable MS. in the possession of the Bibliothèque de Paris, translated by Messrs. Chezy and De Sacy.

nations, however, every belief was based upon some superstition, and they imagined that the gods interfered directly in all great operations of Nature. It is from the last century that we must date the birth of geology. In studying the archives of the primeval world, in whatever part of the terrestrial globe they are found, we discover that a large portion of the earth's present soil has been formed at the bottom of the ocean. The sea-shells which are found in it attest this fact with irresistible evidence. It is a universally known fact that many ordinary building stones contain marine shells, and if we examine a piece of chalk we are astonished at the number of traces of organic life of different kinds which are met with. The calcareous soils which extend over the surface of our continents are, in fact aqueous deposits. The sea formerly flowed over their surface, and the sediments increasing as ages rolled on, have at length formed strata of considerable thickness, filled with relics of the animals which lived in those remote epochs.

In digging into the soil of Paris, we pass through successive layers, each of which indicates to some extent its history by its contents, and the fossils which we find there may be regarded as so many hieroglyphics graven by Nature upon the successive strata.

It is thus that geology has been able to reascend the steps of the past, and unveil the history of the formation of the Paris beds. Excavations made into the heights of Montmartre have enabled the observer to discover the order in which the subjacent strata occur. We find, 1. A bed containing remains of marine animals, indicating that this stratum was once under the ocean. 2. A layer of soil containing remains of land animals, showing that the sea must have retreated from the place which it had previously occupied.

3. A second layer of shells and marine animals, showing that the waters had regained their former dominion, doubtless owing to the subsidence of the soil. 4. A second layer containing traces of creatures which breathe our air, and some of which are almost identical with existing species. 5. A bed testifying by new marine deposits to a fresh invasion of the ocean. 6. Strata in which the débris of our own animals and traces of the implements of human industry indicate the commencement of the modern epoch.

By thus seeking on the surface of the globe for the remains of extinct worlds, and tracing in various countries the successive strata, geologists have been able to construct to some extent the map of Europe as it was before the advent of mankind. The site now occupied by Paris was then submerged, and the shape of the ancient continents bears no resemblance to those now existing. It is possible that we shall one day succeed in deciphering the enigmas that will unravel the mysteries of the past; and, on the other hand, the study of ancient physical revolutions on the face of the globe may to a certain extent enable us to penetrate the future.

BOOK IV.

THE COMPOSITION OF WATER,

AND ITS

PHYSICAL AND CHEMICAL PROPERTIES.

CHAPTER I.

WHAT IS WATER?

The Laboratory.

AFTER having examined the part that water has to play in Nature, let us pursue our investigation yet more closely; let us have recourse to such apparatus as science has brought to bear on the study of the substances we find on the earth. I must tell you that you will not find in a modern laboratory any of the fantastic apparatus which you are perhaps prepared to see, and with which the alchemists were in the habit of astonishing their visitors. The crocodile has long ceased to yawn from the ceiling, the groaning bellows no longer blow up the glowing furnace. The student of Nature has thrown aside his quaint robe, and is no longer absorbed in the labyrinth of dusty volumes which lay in disorderly piles within his sanctuary. Instead of hunting amid this inextricable medley of old books for the truth which is so rarely found there, his efforts are now directed to the study of Nature through facts, and to the interrogating of her by means of experiment; climbing in this way laboriously the steep path of methodical study, he at length reaches by means of observation truths which thus only can be discovered.

We shall find in our laboratory glasses in readiness to receive fluids which are to be poured into them; beakers, flasks, and retorts, intended to be subjected to the action of heat; gas stoves will be kindled at the touch of a match, furnishing us instantaneously with a high temperature without the aid of the traditional bellows; batteries will give as we require them either a powerful electric current, or a brilliant light; a pneumatic machine will produce a vacuum, if we need one for our experiments; a chemical balance will assist us in our analysis; a barometer will indicate the atmospheric pressure; a thermometer and other instruments will each in turn supply our wants.

Perhaps, my reader, you rather regret the disappearance of the old alchemist with his strange apparatus, and the dust which covered it. If you have a taste for the picturesque, you doubtless deplore the absence of the crocodile stuffed with hay, and you exclaim at not seeing the serpent preserved in spirits, nor the pelican, the skeleton, or the spider's web.

Our laboratory has torn away all the charming mystery which surrounded these studies; but instead of speaking confusedly to your imagination, it will in clear language address your reason. This half light, this mysterious obscurity which hung over the sanctuary of the alchemist, was superstition, the false dominating over the true. These fantastic ornaments represent that element of the marvellous which always haunts the first footsteps of science and retards its development. This old sage, who has for sixty years been trying to decipher the same musty conjuring book, what is he but a representative of misdirected science, of man asking truth of his fellow-men ignorant as himself, instead of asking it of Nature, which conceals it indeed, but will assuredly reveal it to the patient seeker.

Our laboratory, clean, well lighted, orderly, is representative of modern science, simple, accurate, stripped of its unintelligible jargon, of its harsh and repulsive aspect, offering to all the secrets which she formerly kept for her few initiated ones. She no longer affects abstract terms, mysterious and high-sounding phrases. Free from all disguise, she addresses herself to all, and aims at being understood by all. We begin our researches by decomposing water—that is to say, by submitting it to analysis.

Analysis and Synthesis.

Here is a glass vase called a voltameter (Fig. 23). We shall fill it with water, slightly acidified with sulphuric acid. By the aid of a galvanic pile, we cause to pass through the voltameter an electric current, conducted by two platinum wires, which pass through the varnished bottom with which our apparatus is furnished. The water becomes decomposed, and the wires are immediately covered with little gaseous bubbles which have been evolved. How are these gases to be collected and examined? Nothing can be simpler. We put into the vessel, over the platinum wires, two small test glasses, which soon become filled with gas. We observe that the volume of gas which escapes from the wire corresponding with one pole of the pile is twice the amount of that of the other gas issuing from the other pole. We remove the first test glass from the voltaic battery, and then apply a lighted match to its orifice, and we find that the enclosed gas immediately ignites, with a slight detonating sound. Let us now plunge into the second test glass a match so nearly extinguished as only to offer a single incandescent point, we shall see the match take fire

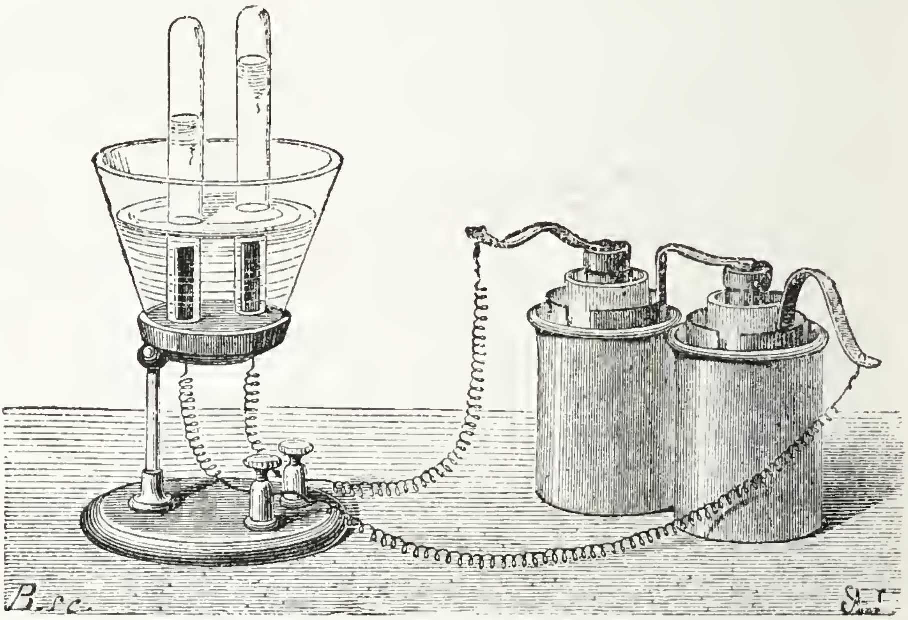

FIG. 23.—VOLTAMETER.

immediately and burn up brightly. The gas contained in this tube, though not itself inflammable, can yet support combustion. In this experiment we have decomposed water, and have extracted from it two distinct gases, one of which burns with a dull flame, and is called hydrogen; whilst the other, which does not take fire, but supports combustion in another body, is called oxygen.

There are a great number of other experiments by which water can be decomposed. I throw into a flask containing

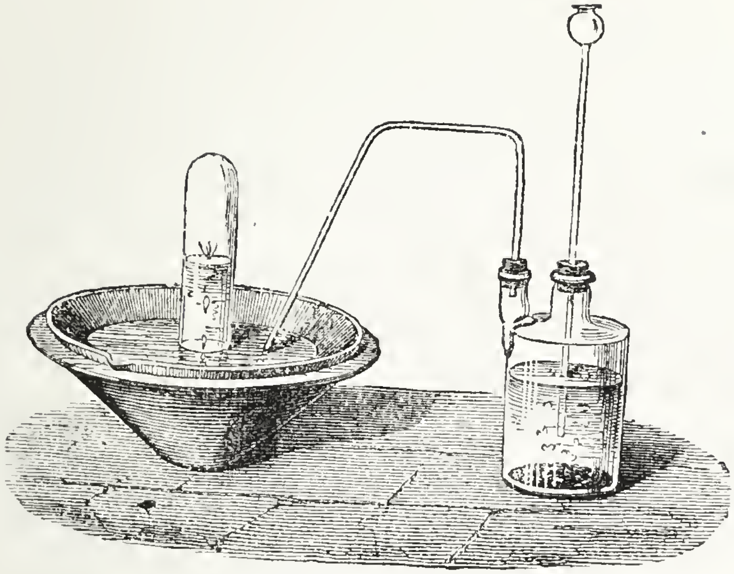

FIG. 24.

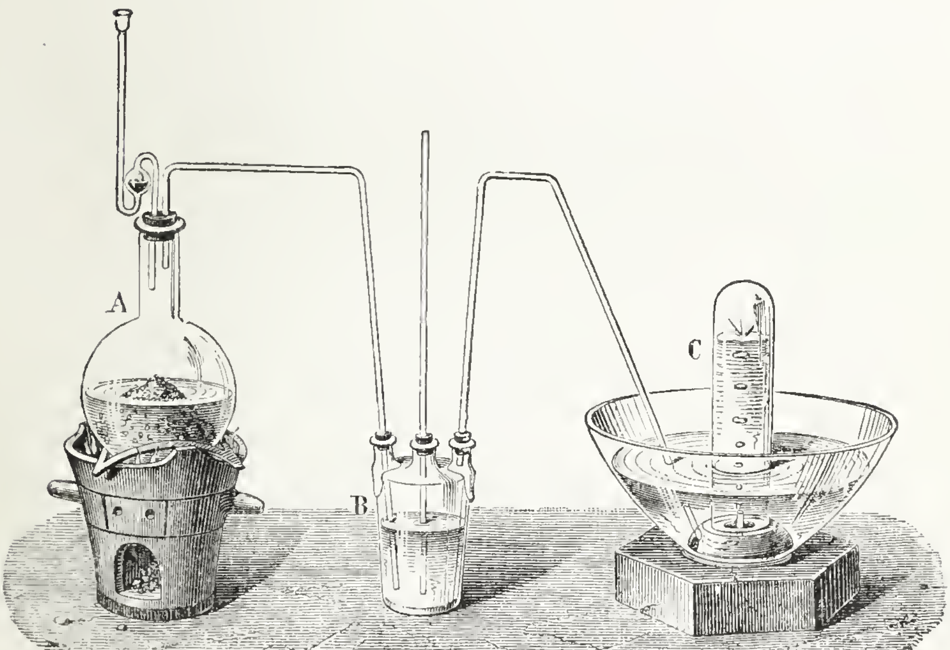

FIG. 25.

zinc, water mixed with sulphuric acid (Fig. 24); the zinc, under the influence of the acid, takes away from the water one of its constituents—oxygen: the hydrogen thus set at liberty, can be collected. The other constituent of water, oxygen, can be produced by heating in a retort a mixture of chlorate of potash and oxide of manganese (Fig. 25). Oxygen is thus very easily obtained, so as to enable us to study its properties. This gas, as we have seen, can support combustion; sulphur and phosphorus burn in it much more freely than in the air,

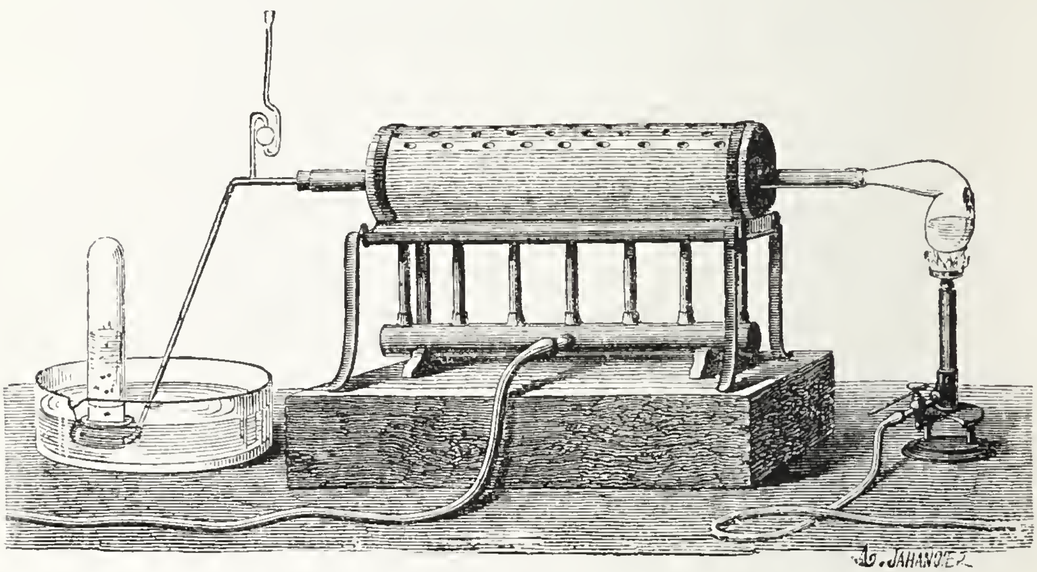

FIG. 26.

and if a steel spiral spring, to which is attached a piece of ignited sulphur, be plunged into oxygen, the metal burns with great brilliancy, numerous bright sparks escaping from the now incandescent steel. Other metals, such as iron, decompose water by mere contact, but it is necessary to heat the metal to a red heat. If we introduce steam into a tube filled with iron shavings, heated from below by gas-burners (Fig. 26), the water becomes decomposed by contact with the incandescent metal, and the oxygen is fixed in the condition of

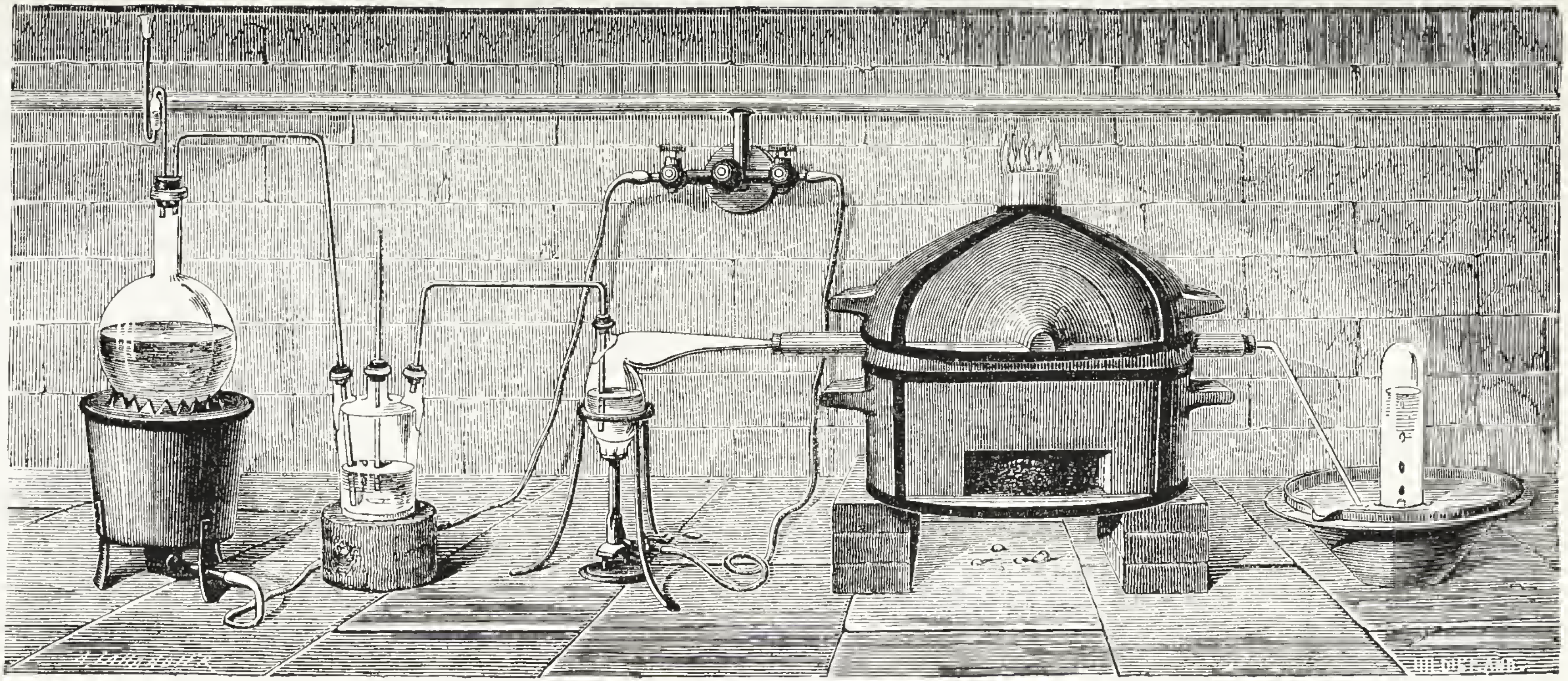

FIG. 27.

oxide of iron: the hydrogen being set free, passes through a tube into a test glass, placed in a basin filled with water. This decomposition may be represented by the following table:—

Water . .	Hydrogen	Hydrogen.
	Oxygen	. . . . . Oxide of Iron.
Iron		

Chlorine, a greenish-yellow gas, also decomposes water under a high temperature; for the chlorine combines with the hydrogen, and sets the oxygen at liberty. The decomposition is effected by the apparatus represented in Fig. 27. The chlorine is produced in a glass flask of a spherical form, containing peroxide of manganese and hydrochloric acid; the gas passes from the flask into a glass retort containing water heated to boiling. The mixture of chlorine and steam thus produced penetrates through pumice stone made red hot; the hydrogen of the water combines with the chlorine, and gives as its result hydrochloric acid, which passes with the oxygen now set free into a pan filled with water, in which a receiver is plunged. The hydrochloric acid dissolves in the water, while the oxygen, which is scarcely soluble, fills the receiver.

We have thus, by these experiments, destroyed and analysed water, which is not, as the ancients believed, a simple elementary body, but is formed of two distinct elements. Up to the present we have been content to destroy, to tear asunder a particle of water into its two components; but can the fragments be reunited in our hands? Can we form artificial water with oxygen and hydrogen? Nothing is simpler.

The accompanying illustration (Fig. 28) shows an apparatus by means of which the problem can be solved. A flask contains the combination of zinc and dilute acid which produces hydrogen. The gas is dried by passing through a tube filled with pieces of chloride of calcium, and when the dried hydrogen emerges at the extremity of a bent tube, it is set on fire. A bell-glass is then placed over the flame, and soon becomes covered with a cloud of steam—even drops trickle down its sides and fall into a vessel beneath. This liquid is water artificially fabricated. The hydrogen, as it

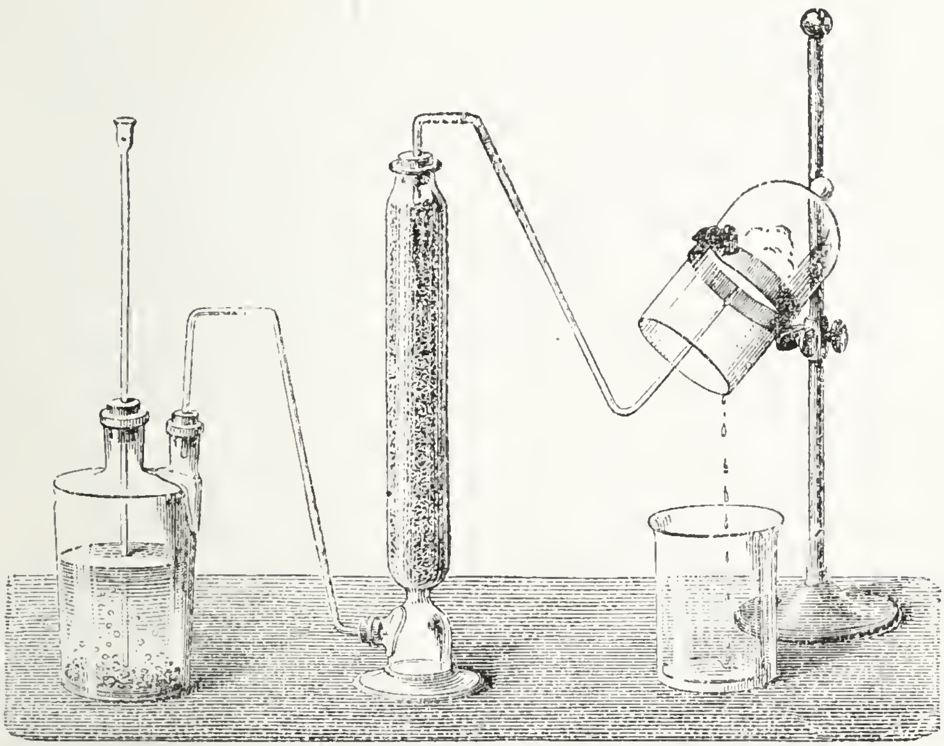

FIG. 28.

burns in the air, becomes united with the atmospheric oxygen, and together they produce water. We have thus accomplished the synthesis of water. Can anything be more conclusive than these experiments, in which the nature of water is shown both with clearness and with certainty? It has, however, taken many centuries to learn the composition of water, and the doctrine of the four elements has been handed down from age to age, to be demolished only at the end of the last century. The doctrine of Aristotle on the subject of the four elements was, in the belief of the ancients, as indisputable a truth as any axiom in mathematics; we are defied to gainsay the opinion of the illustrious tutor of Alexander. In tracing the progress of scientific knowledge among mankind, we see the injurious effects of this subservience to the Greek philosopher, in the unquestioning deference which was paid to his ideas on these subjects, and the manner in which free thought was crushed to enable science to remain in that beaten track first marked out for her by Aristotle.

Man, in the presence of that universe which it is his mission to study, may be considered as looking upon an admirably-contrived clock, the works of which he is to investigate. He may indulge in endless reflections and speculations touching the motive power which keeps the pendulum and hands in motion, he may add hypothesis to hypothesis, theory to theory, without reaching the truth; and even admitting that by a marvellous intuition he succeeds in guessing at the secret spring, in comprehending the mechanism of the clock, his assertions will always be haunted by secret doubts, because it is impossible to arrive at certain conclusions without close observation, positive proof, and demonstrative evidence.

But if he examine this clock attentively, if he carefully take to pieces the first part of its works which offers itself to his view, if he separate the wheel-gear, carefully studying the lesson which is given him to learn, it will not be long ere he discovers the mainspring of steel which puts the whole machine in motion; and if he be sufficiently skilful to restore the various portions to their respective places, and to set the mainspring again in action, he will see the pendulum resume its regular beat, he will behold the wheel-gear once more in motion, and the hands passing over the dial. He will now comprehend that mechanism the different portions of which he has been examining separately, and which he has found how to reunite; he will now say with certainty, "It is no hidden genius which animates this inert matter, it is no mysterious fluid gives life to this piece of mechanism. A stretched spring communicates its movement to a series of admirably arranged pieces, to a succession of wheels following one another, which, in their turn, impart to the hands the motion which carries them over the divisions of the dial-plate."

The chemist, in dissecting the body of Nature, proceeds in the same manner. When he studies a substance, he separates it into its component elements; he takes to pieces its different parts, and thus analyses it. He then occupies himself in putting together again the portions which he has been separating—in uniting the elements which he has been dividing; in fact, in the work of synthesis.

In glancing at the infinite number of objects, organic and inorganic, which cover the surface of the globe—plants of every description, animals the most various, minerals of all sorts—one might feel tempted to believe that an innumerable quantity of distinct elements composed this vast array of bodies so different. But such is not the case. If we analyse the whole body of Nature, trees and animals, stones and rocks, water and air, we are compelled to admit that a limited number of elements, united by twos, by threes, by fours, form the infinite variety of objects which constitute the magnificent spectacle we term the universe. The air is formed by a mixture of the gases nitrogen and oxygen; water contains one of the atmospheric gases, oxygen, united to another gas, hydrogen; vegetable and animal substances are again formed of hydrogen, oxygen, nitrogen, and carbon. If to these elements be added sulphur, phosphorus, potassium, sodium, aluminum, calcium, silicium, iron, and some others, you will have a list of the chief bodies which, by their union, compose all substances living or inanimate.

Wheat and hemlock, food and poison, are formed of the same constituent elements; and about sixty-four simple elements alone are found upon the earth and all that is therein. But it is possible, if not probable, that even some of what *we* call elements are not after all the elements of Nature. The day may come, perchance, in which science will subdivide many so-called simple substances, as we are now dividing water, that element of the ancients, into oxygen and hydrogen.

There is not, however, anything so very astonishing in the diversity of beings produced by a few elements. The arrangement of the various atoms is the cause of the diversity. Diamond and charcoal have the same chemical composition, and yet present as great diversity of appearance as exists between an animal and a plant.

The twenty-six letters of the alphabet are the source of that infinity of words which paint every shade of human thought. The primitive elements are the letters of Nature's alphabet; living beings, minerals, may be considered as the words in that great book of Nature which strikes our imagination and speaks to our reason in sublime language. So is it with the eight notes of music, which by their combination produce every harmony which can charm the ear; and the rainbow's seven colours, which produce every tint in earth or sky.

The Composition of Water.

We know that water is compounded of oxygen and hydrogen, but in what proportion are these two gases united? That is the question on which we are now about to enter. We will introduce into an eudiometer inverted in a basin of mercury (Fig. 29) two volumes of

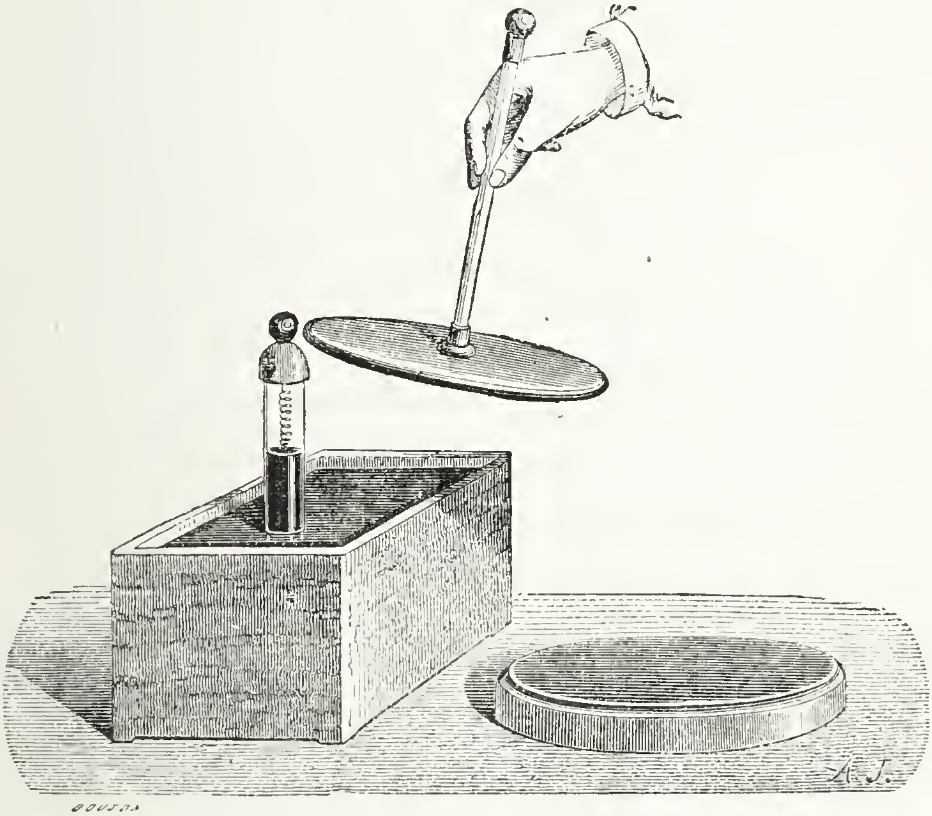

FIG. 29.

oxygen and two of hydrogen; by means of an electrophorus we cause an electric spark to pass into the two mixed gases; they unite, and form water, which becoming condensed, produces a vacuum in the apparatus which the mercury fills. After the experiment, there will remain in the eudio-

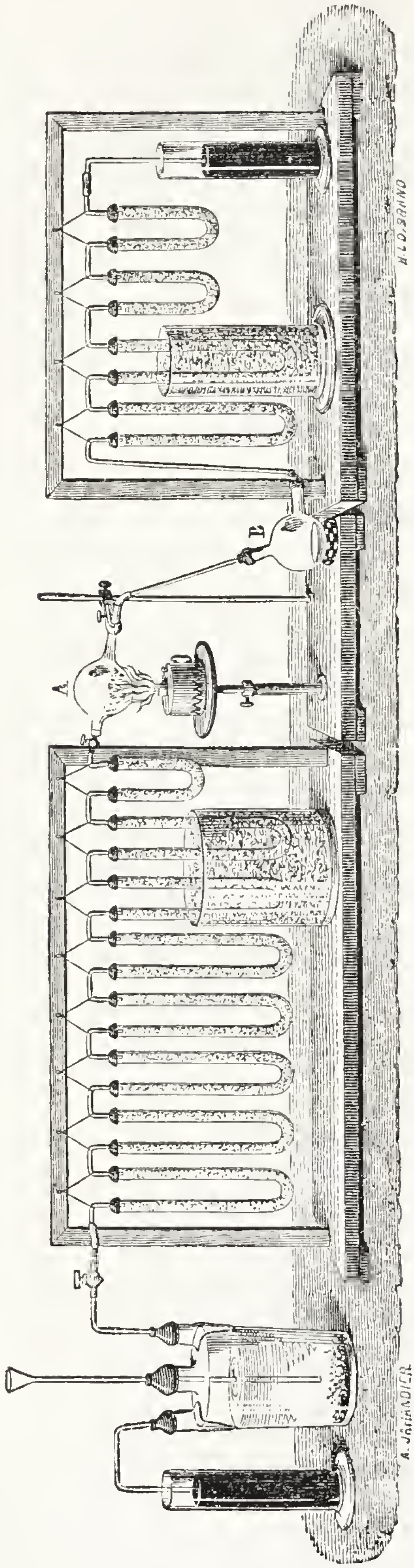

FIG. 30.—DUMAS' APPARATUS.

meter one volume of oxygen, from which we arrive at the conclusion that two volumes of hydrogen and one of oxygen become condensed to form water. From the densities of the gases it can be shown that two volumes of hydrogen and one volume of oxygen condense to form two volumes of steam.

This result may be verified by a celebrated experiment due to M. Dumas, by means of an apparatus represented by Fig. 30, and the principle of which we shall describe. A current of pure hydrogen passes over an ascertained weight of oxide of copper in a glass balloon, A. The oxide of copper becomes reduced—that is to say, the oxygen leaves the copper and unites with hydrogen to form water, which water becomes condensed in the glass receiver, B. By weighing the reduced copper after the experiment, we shall have the weight of the oxygen which has combined to form a known weight of water, whence the weight of hydrogen contained in the water is inferred. These investigations have proved that nine grammes of water were formed of eight grammes of oxygen, united with one of hydrogen. The composition of water may thus be described in a couple of lines, but what a long array of centuries, what an army of pioneers were needed ere these simple facts became known to mankind. Cavendish, Lemery, Lavoisier, Volta, Humboldt, Gay-Lussac, Dumas, such were the men by whose labours the nature of water has been revealed. Two gases, hydrogen and oxygen. Is it possible that water contains nothing else? Water, when *chemically pure*, does contain nothing else, but *pure* water does not exist in Nature. The water of springs and rivers dissolves salts, and, little by little, wears away the rocks which it meets with in its course—it dissolves the gases of the air, the oxygen, nitrogen, and carbonic acid; it contains common salt, sulphate of lime, and calcareous matter—in one word, it contains all that is soluble upon the earth.

CHAPTER II.

THE ACTION OF HEAT.

Ebullition.

HEAT acts upon the majority of bodies, and usually changes their condition; that is to say, it fuses solids, and causes liquids to evaporate. We know water under three aspects, as a solid, a liquid, and a gas. Heat melts ice and causes it to pass into a liquid state, and again volatilises the water and causes it to pass into a condition of vapour.

In order that we may better understand the action and effect of heat, we will warm some water in a glass vessel, and then plunge therein a thermometer, which will indicate the temperature. The thermometer rises gradually until the water reaches boiling point. The thermometer is then at 100°, and from that moment ceases to rise, yet the fire furnishes always the same amount of heat; what then becomes of the heat? It is absorbed by the liquid. Heat forces asunder the molecules of the water, and causes them to pass into the gaseous state; and when thus absorbed heat is insensible to the thermometer. Water boils at the temperature of 100° when submitted to the ordinary atmospheric pressure. The atmosphere presses heavily upon the water, and, in some sort compresses the molecules of the liquid, so as to prevent their separating, and passing from the fluid into the gaseous state

Here (Fig. 31) is a flask containing water, in which we can form a vacuum, by the aid of an india-rubber tube which is

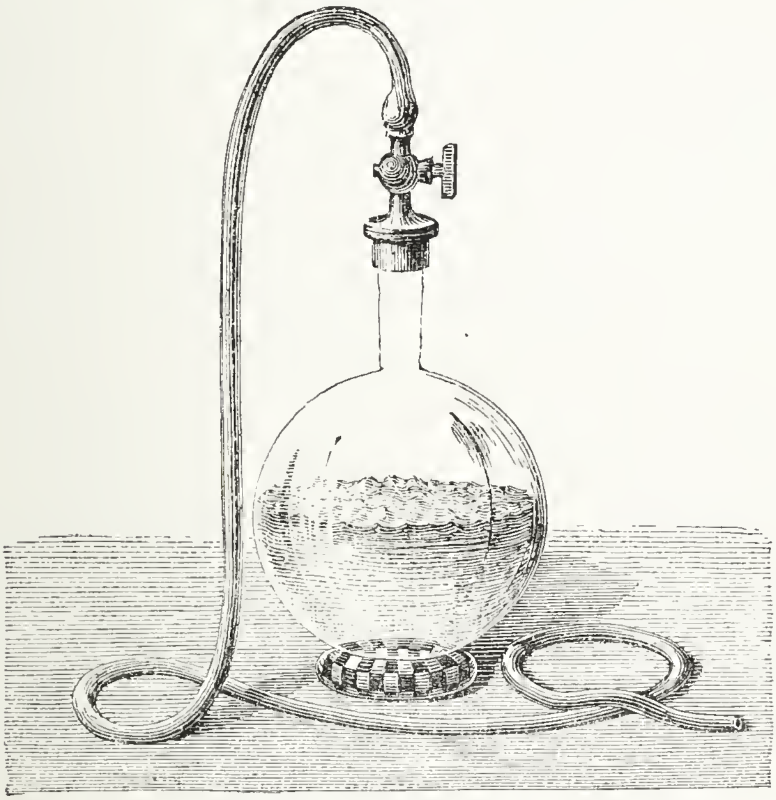

FIG. 31.

fixed to the plate of an air pump. The water boils and becomes turned into steam, in consequence of the removal of the air, though the water is not above the ordinary temperature of the room.

When the barometer marks 29·92 inches of pressure, water boils at a temperature of 100°. Th fnn ogt ipobie io water at this pressure is a standard point on the thermometer. As the pressure varies, as it augments or diminishes, the boiling point augments or diminishes also. When the pressure is beyond 29·92 inches, water boils at a temperature above 100°. Papin's apparatus consists of a closed copper vessel, half filled with water, and heated externally. The steam which is produced, not being permitted to escape, compresses the water and prevents its boiling at 100°; it is thus possible to keep water still liquid at a temperature of from 100° to 300°.

If one pound of mercury at 100° be mixed with one pound of water at 0°, the mixture will have a temperature of 3°; the quantity of heat given out by the mercury in descending from 100° to 3° only heats the water up to 3°. Water is said to have therefore, a great capacity for heat.

The capacity of water for heat explains why islands and countries largely surrounded with water have a mild climate, and enjoy a temperature nearly uniform. In summer the water of the sea stores up the heat of the sun, and retains it to mitigate the rigour of the winters; this is why the Gulf Stream reaches the polar ice still warm.

When the vapour of water is cooled, it returns to the liquid state. We will boil some water in a retort furnished with a condenser (Fig. 32). The steam passes over, becomes cooled in the receiver, and condenses into the liquid state. In assuming the gaseous form water abandons the substances which it held in solution, and is condensed in a state of purity. Hence it is that the vapour which escapes from the sea, forms pure water in the clouds. The operation we have just been engaged upon, is distillation, and chemists frequently employ a distilling apparatus when they wish to obtain pure water.

The apparatus employed for distillation on a large scale is thus described. A copper boiler contains the liquid which is to be distilled. The neck attached to the boiler is adapted to a spiral tube in a vessel of cold water, which is intended to condense the vapour. The cold water enters the refrigerator by the lower part, whilst the hot escapes by the upper part.

The first portions of the condensed vapour are rejected;

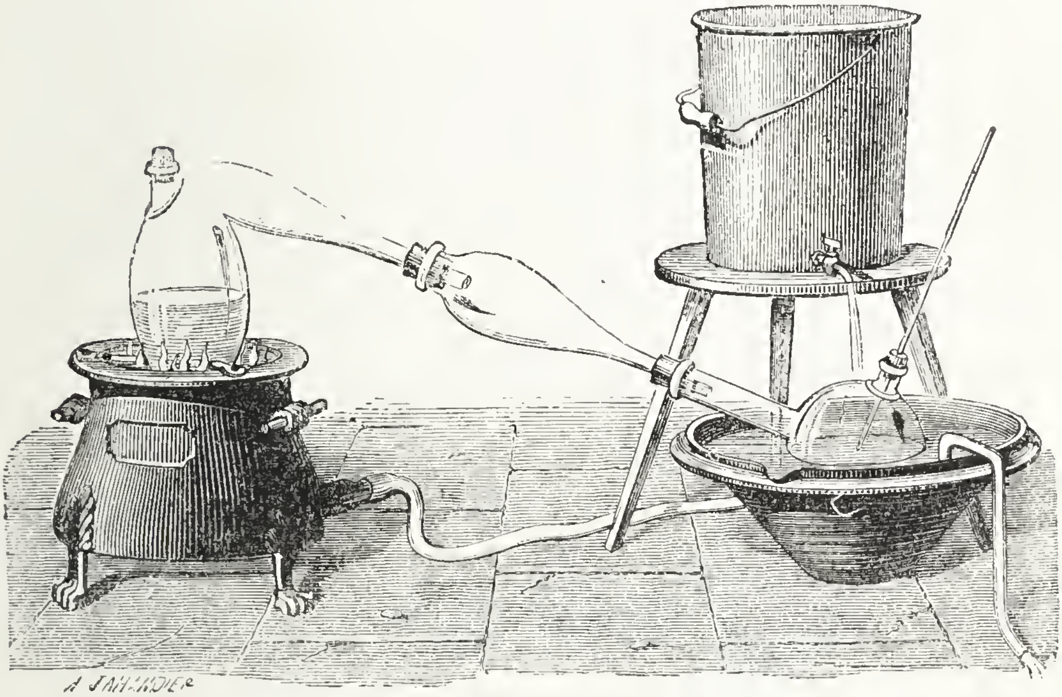

FIG. 32.

they contain the gas held in solution by the water. Those that are afterwards collected are pure.

This apparatus shows us that steam in condensing throws off heat. This explains how it is that a cloud, when condensing to form rain, produces heat, and thus it may be said that the clouds convey heat—and bring the solar rays of the tropics into cold countries.

CHAPTER III.

INFLUENCE OF COLD.

WHEN a body is heated, whether it be solid, liquid, or gaseous, its volume generally becomes larger; but to this rule there are exceptions. Let us cool three spherical glass receivers, A, B, C, Fig. 33, the first of which contains mercury, the second water, and the third alcohol. We plunge the receivers into the same vessel, which we have filled with water, and into which we will throw pieces of ice. The temperature of the water in the vase, shown by means of a thermometer, is at first 15°; the three liquids will cool, their level will gradually sink lower and lower, and the phenomenon will continue till the thermometer has reached 4°; at the temperature of 4°, water ceases to act like the two other liquids, for while they continue to contract, the water now commences to dilate.

At the temperature of 4° the water ceases to contract, it reaches its minimum volume and maximum density. Below 4° the water dilates again, until it assumes the solid form; and in becoming ice, the dilatation is sudden and considerable. We shall find that this property is of great importance in the economy of Nature.

Let us examine what occurs in a lake exposed to the cold of winter. The surface of the water cools and contracts till the temperature reaches 4°. The water thus becomes heavier, and sinks by the excess of its weight, and is replaced by lower and less heavy layers. These new liquid strata, coming in contact with the icy atmosphere, speedily attain a temperature of 4°; they fall in their turn, and so in succession, until the entire lake has reached the same temperature of 4°.

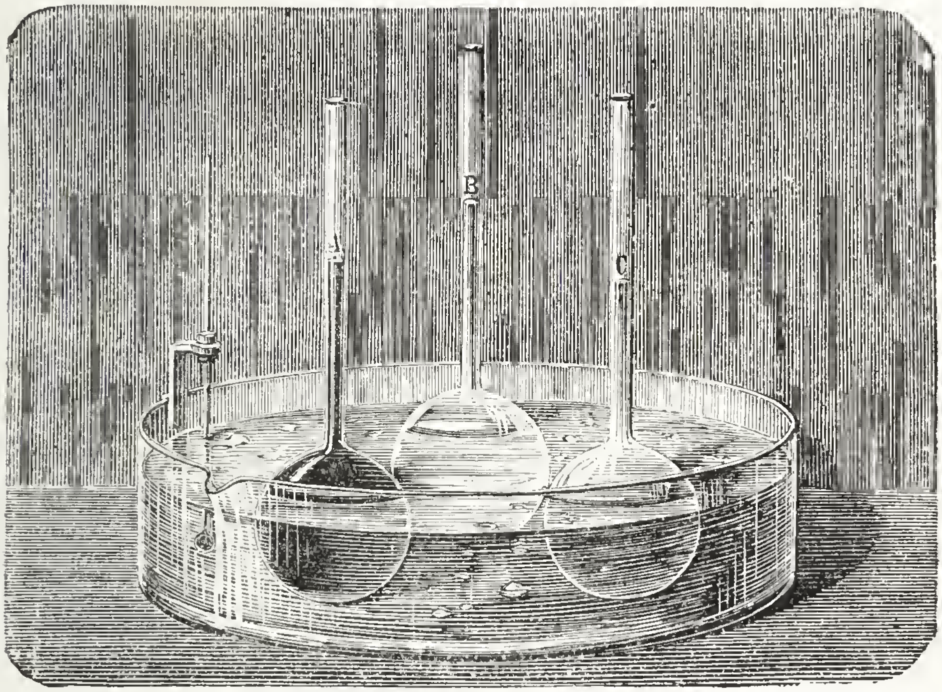

FIG. 33.

The upper strata continue subject to the influence of cold, but below 4° they augment in volume, become lighter, and remain on the surface of the lake. At 0° the surface freezes, and the ice floats upon the mass of water of which the temperature of 4° is sufficiently high to permit the living creatures which it contains to prolong their existence. Were it otherwise, if the water, when it became frozen, diminished its bulk, the ice, being heavier than the water, would sink to the bottom of the vast reservoirs which Nature presents, and would there form a solid mass, of which the thickness would be perpetually augmenting through the winter months.

Rivers and water-courses would be, during severe winters, compact and frozen, and cause, by their compete solidification, the most deplorable consequences. But during the winter, when the peril is most imminent, Nature obliges the water to dilate in consequence of the cold; the ice soon floats upon the rivers, covering them with a protecting mantle, sheltering the living creatures which it covers, and screening them beneath its kindly folds.

The dilatation of water by congelation produces an irresistible force, capable of breaking the most solid substances. Builders are well aware that some stones are broken by the action of frost. A good test of the capacity of the stone to resist the action of frost on the water in its interstices is to plunge a specimen into a concentrated solution of sulphate of soda. The stone when taken out of the liquid will be found to crack after a short time, if it be of bad quality, on account of the expansion produced by the crystallisation of the salt. We will take a tube of wrought iron, nearly half an inch thick. We fill it with water, and stop it hermetically at one end with a screw. The tube is then placed in a refrigerating mixture, consisting of pounded ice and common salt. The water in the tube will soon sink to a temperature of 4°, when contraction ceases. As the temperature descends to 3°, to 1°, and 0°, the bulk of the water increases, and it passes from the liquid to the solid state. In order to effect this transformation of its molecules, the water requires wider space than that afforded by its narrow prison, while the iron tube prevents the water from enlarging. But we shall find that the liquid will not be constrained by the metallic walls which seek to confine it. The water has reached a temperature of 0°, and congelation is inevitable. It is about to burst the bonds of iron. The liquid atoms gain irresistible strength, and the tube of iron is broken by the icy crystals. If you increase the resistance, if you imprison the water in a cast-iron shell, the effect will be still the same. The rigidity of the metal will be conquered in a struggle against a force which has been estimated at a pressure of 1,000 atmospheres.

This explains how, during the winter, our water-pipes are often burst by the frost. The ice breaks the pipes, and when the thaw follows, the water trickles through cracks thus opened. This is why flowers and vegetables are unable to resist the action of frost. The sap which circulates in their stems solidifies. It increases in bulk, and breaks its vegetable covering, dealing at the same time a death-blow to the plant of which hitherto it has been the life.

CHAPTER IV.

SOLID WATER.

THIS block of ice does not appear at first sight to be more interesting than a block of glass; but to the enlightened mind of the philosopher, ice is to glass what an oratorio of Handel's is to the cries of the market and the street. Ice is as the music, glass as the mere noise; ice is order, glass confusion.

The Architecture of Atoms.

There are some works of art which, at a first glance, excite our admiration, but which do not bear close examination. Others there are which, like the carving of Cellini, must be seen close to be enjoyed. In examining the details of such a work, you see that the smallest portions of it have been wrought by a master's hand, and that parts the least apparent have been the objects of the most painstaking skill. You discover everywhere traces of a conscientious artist in love with his work. But the hand of Nature may be seen elaborating the most minute details with a carefulness not to be found in the works of the most painstaking of human artists. Our unaided eye is often unable to follow her into these minute details, and some of her loveliest masterpieces can only be seen with the help of a microscope.

Snow, for instance, is no confused aggregate of solid particles, but is formed of a number of aqueous atoms, symmetrically grouped and possessing an infinite variety of forms. If you assist your natural powers of sight with a microscope, a flake of snow will present to you the appearance of a regular geometrical pattern, symmetrically arranged round a centre. One flake will perhaps resemble a flower with six petals; another a hexagonal star cut with the most exquisite delicacy; and there are snow stars of every variety of shape. These flakes are all, however, constructed on the same model, fashioned from the same type. From a central nucleus six needles radiate, the angle between every consecutive pair being 60°. From these needles ramify other small ones; to right and left branch forth sprays a thousand times more slender, but still faithfully inclined at an angle of 60°. These snow flowers assume the most marvellous forms, and present the most varied aspects; one might mistake them for the ever-shifting images of the kaleidoscope; they are carved in the most delicate material, embroidered on the daintiest muslin.

This is what may be seen in the snow-flakes; but your observations must be very rapid, for this exquisite architecture has but a short duration. A single gleam of sunshine is sufficient to destroy all the edifice, and the mere heat of your body may melt the fragile snow-flake. Then the atoms will separate and the stars will disappear—a single drop of water has replaced the fairy spectacle.

Ice, like snow, possesses a structure of admirable regularity. It is formed of geometrical crystals, which can be shown by the aid of heat.

Let us pass a ray from the electric light through a piece of ice. The luminous intensity of the beam does not change in traversing the transparent block, but its calorific intensity is noticeably diminished, as can be demonstrated by the help of a thermometer. A certain amount of heat has remained in the ice, and will there act the part of a skilful anatomist, dissecting in a marvellous manner the solidified block of water.

If a lens be placed before the block of ice in the middle of the ray of light, so as to project the image of the ice on a screen, we shall see stars with six rays and flowers having six petals. The luminous ray here becomes the messenger who informs us of the work of dissection, which has been wrought by heat in the block of ice. The heat melts the water which has become solidified; it destroys the structure of ice, it separates the molecules which the atomic forces had built up.

Ice and Glaciers.

Crystals of ice form the fields of ice with which the poles are surrounded; they cover the Alps with a stainless garment, and become metamorphosed into water when the rays of the sun strike the white and shining surface in the spring. But all the snow is not melted in summer. Beyond a certain limit, which is called "the snow-line," everlasting snow reigns. Below that line the heat causes the snow, formed by the cold of winter, to melt completely. But if above this limiting line there were, every winter, a fresh deposit of snow, the mountains would, in the course of ages, be charged with an enormous weight. If the layer of snow merely increased at the rate of one yard a year, the deposit which would have gradually become formed during the course of eighteen centuries, would have amounted to 1,800 yards. And if instead of limiting ourselves to historic ages, we went back to the geological periods, we should find that we must assign to the covering of snow which rests on the tops of our mountains, a thickness absolutely prodigious. But no accumulation of this sort has taken place, and it is impossible that the sun should place for ever on the summits of the mountains the water of which he is for ever robbing the sea.

But by what mechanism do the summits of mountains discharge the excess of snow which crushes them? Immense blocks of snow, and formidable glaciers, are sometimes detached, and form avalanches, which are precipitated into the valleys, where they return to the liquid state; but this rapid and accidental motion is not the only one by which the snow descends from the mountains. Glaciers glide down the declivities slowly and progressively, so that whilst their upper part is situated in the domain of ice, above "the snow-line," their extremities reach the warmer regions, where the snow is constantly being melted by the action of heat. We know how easy it is to agglomerate snow by pressing the flakes together in the hand, and how, by being submitted to a high pressure, they can be made perfectly hard. A snow-ball is merely ice in process of formation. Ice itself is capable of yielding to pressure, and if, consequently, a thick coating of snow extends over a layer of ice, the latter urged by the weight of the snow which stretches over it, will, when on the declivity of a hill, begin gradually to descend.

This movement is always taking place on the slopes of those mountains which are charged with snow; the glacier glides down the side of the hill on which it came into existence, and attains the warmer regions, where it is converted into snow. Between the snow and the glacier is found what is technically termed the "Névé;" this is ice in process of formation; it is agglomerated snow, solid and opaque.

Glaciers are endowed with a singular property, often remarked by tourists; that of fitting themselves into the channels in which they move. They exactly accommodate themselves to the form of the ground on which they rest. We may consider a glacier a semifluid mass, like treacle or soft wax, which, without being absolutely liquid, is yet capable of taking the exact shape of the rock which supports it. The glacier is now flattened, now enlarged, and now contracted, and its centre always advances with more rapidity than its sides. Attempts have been made to explain this curious fact by attributing a property called *viscosity* to ice, but this explanation cannot be admitted without experiment; and even if we are made perfectly sure of the fact, that solidified water yields in the same manner as honey or pitch, we are none the less compelled to seek for the cause of this property of viscosity possessed by ice.

If you take two fragments of ice and place them side by side, their surfaces will unite, and the result will be a single block of ice perfectly homogeneous. This experiment furnishes an explanation of what takes place in Nature.

We owe this curious experiment to Faraday,—it is known under the name "regelation." We are indebted to Dr. Tyndall for other interesting experiments. During a hot day in summer, Dr. Tyndall went into a shop in the Strand, in the window of which some pieces of ice were exposed for sale in a basin. With the permission of the owner of the shop he took them into his hand, and lifting up the topmost piece, made use of it to draw all the rest out of the dish. Though the thermometer was far above freezing-point, the pieces of ice had become welded.

The regelation of ice is effected even in hot water. Two distinct fragments, placed in contact in the midst of a liquid as hot as the hand can bear, will, if held closely together for a few seconds, freeze and agglomerate in spite of the heat. It is by virtue of this regelation that ice acts in a manner similar to a viscid body. Ice breaks as easily as a piece of glass; but the separate pieces become welded one with another, and assume a new form.

A bar of ice, compressed successively within a series of moulds, each more bent than the last, can be transformed into a circular ring. The bar, according to one theory, breaks in the mould, but has scarcely become broken before it freezes again, and forms a single mass homogeneous and compact. It is the same principle which permits the formation of snow-balls, squeezed between the hands. If we violently compress a large snowball in a mould, we can obtain a cup of ice, perfectly transparent, from the regelation of the snow. If the snow be piled up in a spherical mould, a sphere of ice both solid and transparent is obtained.

Those who dwell among the mountains, uninitiated as they are into the theories of physical science, frequently avail themselves of the property of regelation possessed by solidified water, in crossing the deep crevasses by snow-bridges. By stepping with great care over the bridge which the agglomerated snow-flakes form, their strength can be tested, and the mass takes, under the influence of regelation, a hardness and rigidity which renders it capable of supporting a heavy weight. The guides in Switzerland are in the habit of crossing very deep crevasses in this manner.

The reader now understands one of the theories as to how a glacier makes its way through the defiles of the Alps, insinuates itself into the excavations of the soil, penetrates narrow gorges, bends and winds backwards and forwards over the shoulders of the mountains, takes the impress of the furrows which wrinkle hill and valley, and sinks into the crevices of rocks. Ice wears and polishes the surfaces along which it glides; its lower part is filled with pebbles, which perform the same part as do the hard fragments adhering to glass-paper. The ground becomes furrowed by these stones, which move slowly with the glacier. When the glacier has ceased to exist, when it is converted into water under the action of solar heat, it leaves indications of its existence, its channel being covered with the marks which have been traced.

In all chains of mountains, in every country, we see in a great number of places, deep flutings furrowing the rocks, and smoothly-planed surfaces, which speak to the eye of the observer in plain language, testifying that a glacier must have formerly existed in the place where he is now standing. The valley of the Grimsel, in the Bernese Alps, presents an aspect highly characteristic of the action of the glacier. The rocks are rounded and polished, and everywhere is to be found traces of the furrows formed by the pebbles which adhered to the ice. The same features may be observed in the valley of the Rhone, on the sides of the Jura Mountains.

North America and certain parts of Asia have at one time been seas of ice, and the cedars of Lebanon now flourish over the moraines of pre-historic times.

Glaciers, ice, snow, and the *névé*, are not the sole varieties of solidified water which Nature presents to our view. Frequently among the mountains we meet with cavities full of water, on the surface of which layers of ice form themselves, of quite a different character to the glacier-ice. This *water-ice* is more compact than the other kind, and does not contain any of the capillary fissures which colour the ice with that beautiful blue tint so much admired by tourists. At the bottom of rapid rivers, such as the Rhine, are sometimes collected together fragments of a sort of spongy solidified ice, known to the dwellers on the banks by the name of "*bottom-ice.*" Hail, again, presents to us the example of a totally different variety of solid water. The texture of hailstones is not crystalline, but is characterised by concentric layers, disposed round a central nucleus. The ice which forms upon ponds and rivers is the kind which has been most carefully studied. We have shown that this ice has a crystalline structure, a fact we may confirm for ourselves by examining the motley designs which are to be seen on the panes of our windows. M. Haas has discovered a process by which the hoar-frost designs may be retained upon a window. He exposes to cold a horizontal plate of glass, covered with a thin layer of water, holding in suspension enamel powder. The hoar-frost, keeping the enamel powder imprisoned, forms numerous ramified figures. We have, therefore, arborescences of enamel when the ice is evaporated, and by placing in an oven the glass thus dried, we shall cause the melted enamel to fix for ever the crystallised forms traced by the hoar-frost. Ice has, indeed, been often met with in real crystals, formed of hexagonal or triangular prisms. Dr. Clarke took from under the bridge at Cambridge several large rhomboidic crystals of ice. These cases, however, are exceptional, ice seldom presenting a more crystalline structure than glass.

CHAPTER V.

CHEMICAL PROPERTIES OF WATER.

Solution.

THE phenomenon of solution of salt in water, common and well known as it is, possesses considerable interest. We will throw a handful of saltpetre (nitrate of potash) into a vessel filled with water; this salt dissolves readily. We then throw a second handful of the same salt, then a third, then a fourth; but when a certain amount has been dissolved by the liquid, it refuses to take up any more, and the excess of salt remains undissolved at the bottom of the vessel. The water is now said to be *saturated.*

On heating this water, we find the salt which is in excess becomes dissolved, so that when the liquid is in a state of ebullition, it will absorb a much more considerable quantity of salt than it could contain at a lower temperature.

Hot water dissolves the majority of salts with greater facility than cold water. Some salts, however—for example, common kitchen salt—dissolve as well in cold as in boiling water. If we allow warm saturated water to become cold, the water will relinquish the excess of salt by depositing it in geometrical crystals upon the sides of the vessel (Fig. 34). Carbonate of soda, sulphate of copper, and alum, crystallise with great facility in water, and clothe the bottom of the vase in which they are placed with needles and prisms of the most remarkable appearance.

Water does not dissolve all salts in the same proportion; a pint of water can take up more than its own weight of sulphate of soda, whilst it cannot dissolve more than one ten-thousandth part of its own weight of sulphate of lime. Water charged with carbonic acid acts upon a great number of

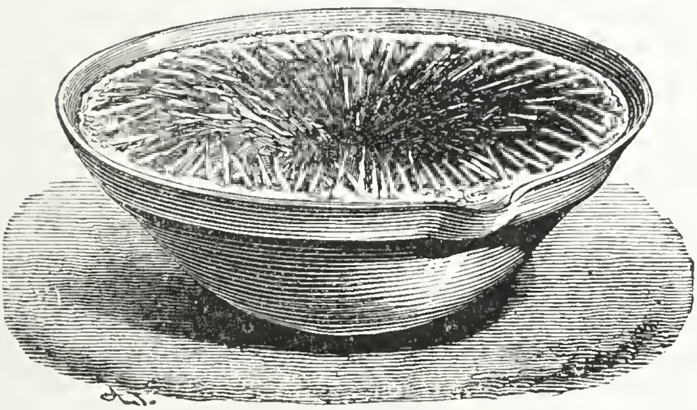

FIG. 34.

stones; it dissolves, as we have seen, carbonate of lime, and can even decompose granite rocks. The union of water with some substances is accompanied by the evolution of heat; thus water, which is not affected by bodies such as gold, silver, quartz, carbon, sulphur, etc., is decomposed by potassium and sodium. So also when water is added to quick-lime, a new compound is formed, with a copious evolution of heat (Fig. 35).

The Colour and Transparency of Salts.

Who would believe that colourless water could colour or render transparent the salts which crystallise in its bosom? Witness the following experiments.

We take some crystals of sulphate of copper which have an exquisite shade of dark blue; their brightness, their transparency, are remarkable, and they reflect the light which plays upon their regular facets. We will confine

FIG. 35.

these crystals in a stove (Fig. 36) heated to 120°, a temperature at which the water evaporates, which was united with the crystals of sulphate of copper. At the end of some hours, the salt will be perfectly dry; but the crystals are destroyed in consequence of the departure of the water; the colour and transparency are no longer in the crystal when deprived of the water of crystallisation. These blue crystals, regular when they contained water, are, now that they have become dry, changed into a white and opaque powder.

We will next take transparent crystals of carbonate of soda. We will dry them, and as soon as they lose the water which they contained, we shall find that they have assumed the appearance of a white and shapeless powder.

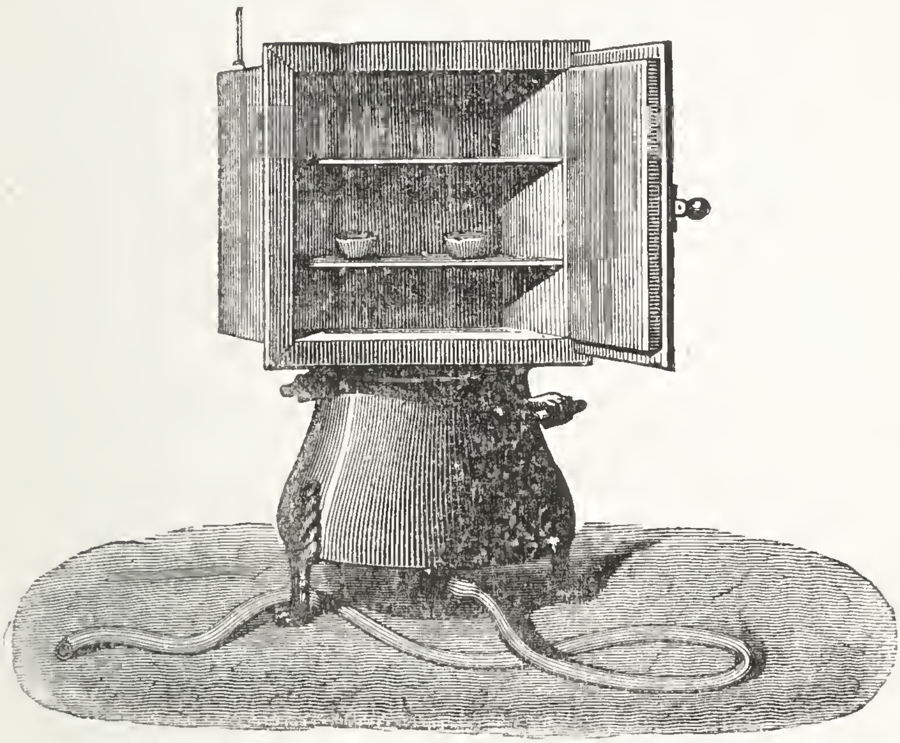

FIG. 36.

The water thus imprisoned in the mass of crystallised bodies is united, according to definite relations, with the molecules of the salt. For instance, five molecules of water unite with one molecule of sulphate of copper to form those beautiful blue crystals, which make such striking objects some chemists' shops.

A large number of minerals contain naturally *water of* *combination*, which is often associated with beautiful transparency. The translucent gypsum which is so frequently met with in the quarries near Paris, is a hydrated sulphate of lime, which possesses a singular crystalline form. This gpysum, when calcined, loses the water which it contains, and becomes transformed into a white powder well known as a plaster. Azurite, one of the most beautiful stones which the mineral world offers to our view, and which has a regular crystalline form and a beautiful dark blue colour, contains also water of crystallisation, and becomes destroyed when the water is expelled, for the mineral then loses the shades of azure which procure for it its name.

Plants and Animals.

Still more important is the chemical part played by water in the animal and vegetable kingdoms. We all know that the liquid element nourishes plants, and we find that it constitutes a great portion of the bulk of the trees of our forests, the fruit and seed of those trees, and the bodies of all animals. The philosopher Thales, the celebrated head of the Ionian school, said, two thousand years ago, "Water is the principle of everything; plants and animals are merely condensed water, and it is into water that they will be resolved after death." This assertion is not so exaggerated as at first sight might appear.

We will warm at a stove a handful of green herbs which have been carefully weighed. We will wait until the water has had time to evaporate, and will then examine the dried plants.

These herbs, green and brilliant, fresh and living, have become dead and calcined from the departure of the water; their weight is diminished by four-fifths; instead of weighing five ounces, they now only weigh but one ounce; and in depriving them of water, we have taken out of them all that constituted their life; we have removed the sap, the colouring matter, we have, in fact, destroyed the whole organism.

All animals, including man, are formed principally of water; the presence of some globules transforms water into blood—a few mineral and organic substances transform water into milk. Pure milk contains 85 per cent. of water, and the blood of animals 97 per cent. A man weighing ten stone would not weigh above two stone if his body were completely dried.

These facts will suffice to give some idea of the extraordinary importance of the part played by water in the constitution of living beings. If water were suddenly to disappear from this world, everything that breathes here below would be annihilated. Seas would dry up, and the animated world, which exists in the ocean, perish. In the place of those liquid plains on which wave follows wave, immense and arid deserts would present themselves to the eye of the spectator.

The rivers, streams, and brooks, which course through the land, would present the appearance of dried-up tracks; the little rills would no longer cause their pleasant murmur to be heard. Trees, plants, vegetables of every sort, would be completely destroyed; in losing the water which they contain, they would lose both their sap and their life; the grandest oak of our forests would be transformed into a crumbling mass.

The majority of stones would also change their appearance; transparent gypsum would become white powder, blue carbonate of copper and the green crystals of malachite would be changed into colourless ashes; building-stone, slate, the strata of coal, would wear an appearance totally different from that which they at present present.

The air deprived of vapour, and the clouds which float within it, would no longer present the magnificent spectacles produced by sunbeams on the clouds; the sun would no longer as he sets tinge the clouds with crimson and gold, and the entire surface of the globe would present a terrible picture of desolation.

BOOK V.

THE USES OF WATER.

CHAPTER I.

WATER AND AGRICULTURE.

WHEN the summer sun has for a long time been burning the parched earth, when the sky has refused the benefits of rain, then the trees, the flowers, and all vegetation appear to mourn and languish; the leaves become flaccid, the branches droop, the meadows lose their brilliant verdure, and the corn bends under the weight of its full ears. If the sky becomes dark, if the thick clouds begin to discharge and moisten the ground with a profusion of rain, then vegetation speedily revives and absorbs with eagerness the precious gift. Everything seems as though newly awakening to life. But the husbandman must not always wait till the clouds bring him that fluid which is necessary for his land; he has to learn how to provide against droughts. Plants, like animals, are born, grow, reproduce themselves, and die. Like animals, they breathe, and like them they imbibe nourishment. Their leaves are the organs of respiration; they absorb the carbonic acid of the air, and under the influence of the solar rays they exhale oxygen and assimilate the carbon necessary to their development. The roots are the organs of imbibition; they search in the soil for such elements as are necessary to the nourishment of vegetable life, and it is water which brings these elements to the roots in a state of solution.

It is not every kind of water that can fertilise the soil and facilitate vegetation; there are some waters which, being injurious to the development of plants, render the earth barren. The stagnant waters of marshes and peat bogs put an end to organic life, being charged with astringent matter which withers the foliage and paralyses the vegetation. Those waters which have been flowing through a very shady country, whose course has been under tall trees, retard the growth of plants; they bring into the fields of grain the seeds of weeds, which spring up to the detriment of the cultivated plant.

Waters from badly aerated sources, those formed from the melting of snow, are injurious both to plants and animals. Such waters are unfit for use until they have been exposed to the air for a considerable time. According to Sinclair, water impregnated with iron has a similar effect upon plants as on animals, and serves to endue grass and herbs with tonic qualities. Those waters which contain an appreciable quantity of sulphate of iron are pernicious, while carbonate of iron is still more injurious. Carbonate of iron encrusts the tissue of plants, closes their pores, obstructs their cells, and gradually kills them. Brackish waters, and even the water of the sea, produce good results if employed with care and in proportion to the dryness of the climate. Every one knows what beneficial effects salt meadows have upon cattle, and the improvement caused in the quality of the meat. The water of streams and that which is bestowed on us by the clouds are equally beneficial and nourishing to the soil.

Irrigation and Drainage.

Have you never found pleasure in cultivating a plant in a flower-pot on your window-sill? Did you not lavish care on the little shrub, the progress of which you were watching? You were present at the birth of the first little bud; you saw it metamorphosed into a beautiful flower with fresh and vivid colouring. How often have you admired its petals at the moment when they were expanding under the caresses of the sun. What made that plant thus grow beneath your eyes? It was the nourishment you supplied every morning in the form of water. In the evening the leaves and petals, exhausted by the heat of the day, had lost their smiling beauty and seemed to droop, but a little water speedily revived them. Did you never remark that the earthen pot which contained your plant was pierced at the lower end with a small hole? Did you not observe that the saucer which held the flower-pot often filled with water while you were watering your plant? The water which had been poured into the pot had traversed the small potful of earth through which the roots expand, and the excess of liquid, not absorbed by the roots, settled in the saucer by means of the hole at the bottom of the pot. Without this hole the water would have remained in the bottom of the pot, and the roots immersed constantly in water would have become decomposed, and thus cause the decay of the plant. Your agriculture has prospered because it was in conformity with the rules of irrigation and drainage, and the husbandman should manage the fields he cultivates on the same principles as the flower-pot. It is by artificial irrigation that the soil is to be ameliorated; but the waters ought to be distributed judiciously, otherwise the land is injured rather than benefited. After having watered the earth, and after the ground has absorbed the water which has been so abundantly poured into it, it is necessary that the excess of liquid should be carried off. Irrigation must be succeeded

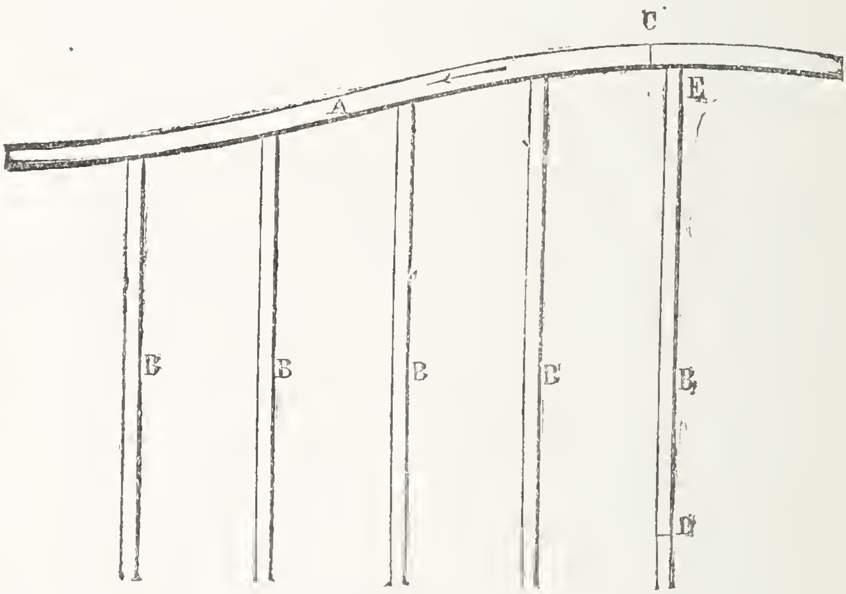

FIG. 37.—IRRIGATION BY INFILTRATION.

by drainage. Irrigation is advantageous to all soils, but especially so in the case of a sandy soil, and if the water be a little muddy or slimy irrigation not only enriches the land by the nourishment it brings, but lessens the porous character of the soil by the sediment which is deposited from the water. It is necessary to understand thoroughly what amount of water is requisite for the purposes of irrigation, the volume with which the stream employed flows, the rapidity of its current, the absorbent nature of the soil, the nature of the climate, all should be the subject of most attentive study.

In warm climates the amount of water employed in each watering should be sufficient to cover the entire irrigated surface to a depth of four inches; or if the water flow continuously on the land, the proper allowance is forty

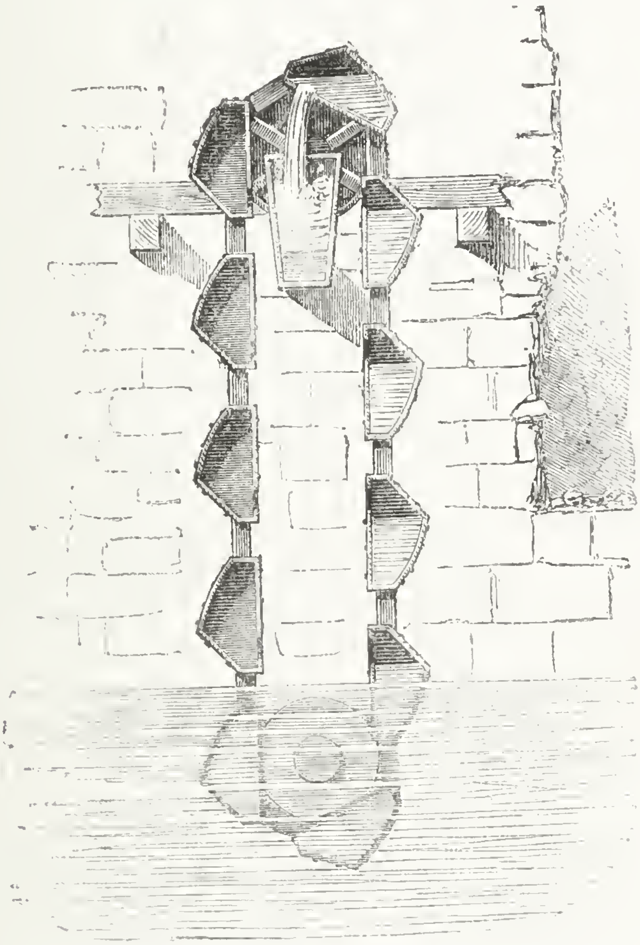

FIG. 38.

tons of water per acre per diem. The water being conveyed to the highest part of a piece of land, the question arises as to how it is to be distributed so as to spread uniformly over the whole surface, and thus benefit all the plants. We shall not attempt to describe all the various methods of irrigation that have been tried, but shall

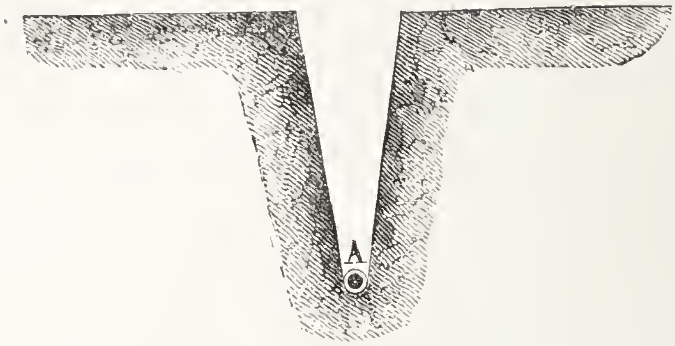

FIG. 39.

briefly describe the plans that have been found most beneficial. Fig. 37 represents irrigation by infiltration. The water arriving by a feeding trench is distributed into other

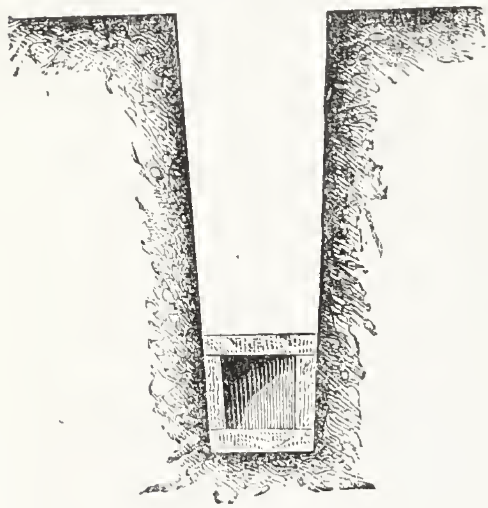

FIG. 40.

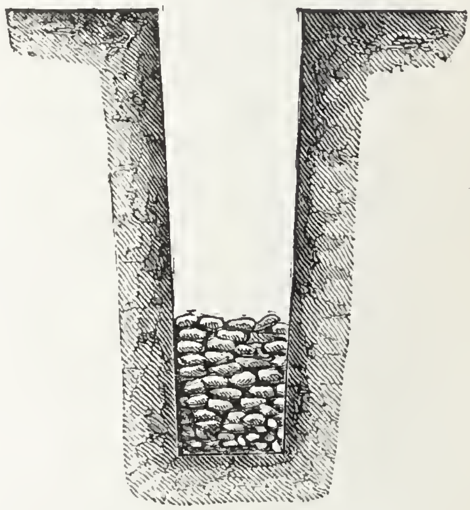

FIG. 41.

secondary trenches, B B. These trenches are simply furrows between those formed by the ploughshare for cultivation.

Water is successively poured into all the secondary trenches. We commence, for example, with the trench which terminates at E, a point on the feeding canal. The feeding canal is closed at C, and the water sinks into the soil as far as D.

It not unfrequently happens that the water occupies a lower level than the field which is to be irrigated, and then it becomes necessary to raise the water by means of machines, one of which is shown in Fig. 38.

By drainage we carry off the superabundant moisture, which might otherwise injure the development of plants.

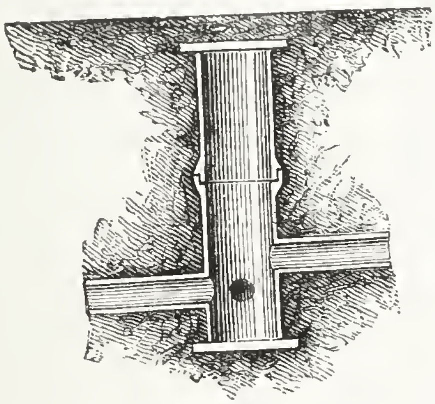

FIG. 42.

Trenches are dug in the land to be drained. At the bottom of these trenches cylindrical pipes are placed (A, Fig. 39). Into this drain is thrown the earth which has been extracted, and nothing appears on the surface of the ground. But the superabundant water within the soil sinks down to the bottom of the drain, and enters the pipes by their joints. These pipes, being on an incline, carry the water from the field to where they discharge into a stream. Occasionally drains are employed of the form shown in Fig. 40, in which a stone channel conveys the water. Sometimes merely loose stones are laid at the bottom of the trench, as in Fig. 41. The drain being situated below the surface, it is sometimes necessary to know how it works. For this purpose the part shown in Fig. 42 is employed. The water enters the vertical pipe by one tube and leaves it by another; a little earth being removed, which conceals the top of the vertical tube, the noise of the water can be heard.

Warping.

Every year the Nile overflows its banks, pours its waters over the surrounding fields, and deposits that loam which, from its fertilising properties, gives wealth to the immense valley through which its waters glide, nature doing that in Egypt which man performs in other countries by a process which is termed warping. The object of this operation is to cause the land to be fertilised with muddy water. The waters are allowed to settle until the sediment is deposited; the pure water as it runs off is replaced by more turbid water, and the process is continued until the soil has received a sufficient supply. Warping is a means of creating, at slight expense, a new and fertile soil.

Agriculture has to provide the means of utilising marshes and swamps. It is necessary for these noxious places to be drained before wheat or other useful crops can replace useless reeds and marsh plants.

CHAPTER II.

SALT WATER.

Sea Salt.

AMONG the most important industrial products a foremost place must be given to sea salt, or chloride of sodium. Sea water contains that invaluable substance which appears at all our meals, and is daily employed in domestic economy to season our food and preserve our meat. A considerable quantity of salt is annually used in agriculture, and the industrial arts employ a vast amount in producing sulphate of soda, hydrochloric acid, and several chlorides of great importance in the chemical arts.

Chloride of sodium is procured from three different sources, from *beds of rock-salt*, from *salt springs*, and from *sea water*. In the former case, when the rock-salt is pure, pits and subterranean galleries are excavated, from which the miners bring forth the valuable commodity. But when the bed of salt is not such as would, either in quantity or quality, repay the trouble of working the mine in this way, a simpler and cheaper method is resorted to. Instead of sending miners into the mines to hew out the salt, fresh water is introduced. In the territory of Salzburg, in Swabia, and in a number of other localities, narrow shafts are sunk into the salt-beds, terminating in large spaces called dissolving chambers. Into these chambers water is poured, which dissolves the rock-salt and becomes saturated. The water is then raised to the level of the ground by the aid of pumps, and evaporated under the action of heat, when the crystals of salt are copiously deposited.

Salt springs arise from the infiltration of water which in its passage through the earth has encountered beds of rock-salt. These waters are rarely saturated with salt, not containing more than 3 to 4 per cent.; in this case the volume of water to be evaporated would necessitate too large an expenditure of heat if applied directly. The solution is first concentrated by exposure to the air in a peculiar apparatus. This consists of bundles of brushwood fixed in wooden frames, and surmounted by small troughs. The salt water is passed into these troughs by means of pumps, and trickles from the troughs upon the brushwood, and the water thus traverses the mass of brushwood, falling drop by drop through its whole thickness. The water being constantly in contact with currents of air, is subjected during its passage to considerable evaporation, and reaches the lower basin in a more concentrated state. If the operation be repeated many times, and if the apparatus be situated in a position exposed to the wind, the evaporation takes place very rapidly. In the salt works of Sooden, near Allendorf, in Hesse, a water which contains 4 per cent. of salt before percolating for the first time through the brushwood, contains 22 per cent. after having percolated six times.

This mode of extracting salt is in frequent use in many countries, in which are erected vast brushwood filters upwards of 500 yards in length, by 13 in height and 4 in

FIG. 43.—SALTERNS UPON THE COAST OF THE MEDITERRANEAN.

breadth. The salt water may be seen trickling slowly through the piled fagots, and then gradually concentrating, until it becomes sufficiently saturated to be subjected to evaporation by fire. When the water is found to contain from fourteen to twenty-two per cent. of salt it is submitted to the action of heat. The impurities are first deposited, and subsequently the chloride of sodium. Of the richest and most abundant sources of salt, the first rank must be given to the ocean. The waters of the sea are evaporated in the South in vast reservoirs, called salterns, by the action of heat which the sun prodigally lavishes. On the shores of the Mediterranean the salt water flows into vast basins, where it evaporates; and when the liquid has attained from 20 to 24 of Beaume's scale it is made to flow into other basins, where the salt is deposited (Fig. 43). These works are of the greatest importance, for the sea water does not merely contain chloride of sodium, but also holds in solution some other salts of considerable utility.

The following table will show the ingredients of one thousand parts of sea water:

	OCEAN.	MEDITERRANEAN.
Chloride of Sodium . . .	25·10	27·22
Chloride of Potassium . .	0·50	0·70
Chloride of Magnesium . .	3·50	6·14
Sulphate of Magnesium . .	5·78	7·02
Sulphate of Calcium . . .	0·15	0·15
Carbonate of Magnesium . .	0·18	0·19
Carbonate of Calcium . . .	0·02	0·01
Carbonate of Potassium . .	0·23	0·21
Iodides, Bromides, &c., in Pure Water	964·54	958·36
Total . .	1000·00	1000·00

Certain lakes contain a still larger proportion of sea salt. The waters of the Dead Sea, and those of the Great Salt Lake in the Mormon country contain as much as eleven per cent., but these abundant sources of salt are exceptional. The waters of salterns, after having abandoned the chloride of sodium they hold in solution, contain also sulphuric acid in the form of sulphates of soda, potash, and magnesia. M. Bellard has devoted himself to a patient study of these waters, and has found that the sulphate of soda can be profitably extracted.

Sulphate of soda is employed in the manufacture both of soda and glass; it is one of the most important chemical products, and the discovery of the method of extracting it from the ocean may be considered as one of the most important modern discoveries.

CHAPTER III.

ICE AND ITS ARTIFICIAL MANUFACTURE.

EVERY one understands the use of ice; it is well known that it preserves organised bodies from putrefaction. The decomposition of a substance requires a certain degree of heat, and fermentation is impossible below a certain temperature. The employment of ice placed in small quantities round fresh meat, fish, etc., enables these perishable articles of food to be kept for several days, and when the temperature is below that of melting ice the length of time during which they can be preserved is still more considerable. In Russia and Siberia animals destined for food are slaughtered at the beginning of winter, the carcasses are frozen and preserved by the cold. In this way the food is saved which the animals would have required during the winter. In the far North, in Greenland and in Davis's Straits, those English sailors who are engaged in the seal fisheries expose beef to the freezing air, and are in this way able to have fresh meat during the whole of their long voyage. In Siberia a fossil elephant has been found admirably preserved in ice. The carcass of this antediluvian animal having been imprisoned during centuries in an icy covering, the flesh was found as fresh as that of an animal just struck down by the hunter.

The culinary art makes daily use of ice in the preparation of cooling drinks, the consumption of which is so great during the summer months. The articles to be cooled are enclosed in a vessel which is plunged into a mixture of ice and salt (Fig. 44).

Medicine also finds in ice a valuable remedy against cer-

FIG. 44.

tain maladies. A vast quantity of rough ice is brought every year, at great expense, in ships from Norway and other cold countries. We may, therefore, infer that any machines for artificially producing ice at a moderate cost would be of great importance. Drinks cooled by means of ice were appreciated as highly by the ancients as by our modern gourmands.

The Romans had learnt how to preserve snow and ice in caves, which answered the same purpose as our ice-houses, and snow-water was with them a favourite beverage. At night chariots covered with straw brought the snow of the Apennines to the ancient capital of the world. Galleys transported into Italy the ice of Sicily, which was considered preferable to all others in the opinion of the ancient gastronomers, because it had been formed in the vicinity of burning craters in which lava boiled. A temple was erected for the sole purpose of preserving the snow during the summer, and the priests of Vulcan drew therefrom an enormous income. Christian priests afterwards kept up this good custom, and the Bishop of Catania at the end of the last century obtained a large sum annually from the working of a mass of snow which he possessed on Mount Ætna.

At the present day, as in classical times, the Ural and Caucasian Mountains supply the East. Ice packed in skins and enveloped in straw is transported on horseback. In France the consumption of ice has not as yet become considerable, but in the United States of America it has attained enormous proportions. Collected during the winter on the immense lakes of Canada, it is divided into blocks, and transported to Boston, whence ships convey it to the Antilles, the Cape, and even to Australia. The city of Boston alone consumes annually 100,000 tons of ice, and 4,000 workmen are employed in this branch of commerce. Norway is the ice-house of Europe, from which other countries draw supplies.

Gouland's Apparatus.

In order to convert a certain volume of water into ice it is necessary to cool this water; or, in other words, to ubtract its heat. Cold is not, as has been imagined, a reals physical agent of which the properties are exactly opposed to heat; a body is said to be cold by contrast with a body that is warm. How is the water which we wish to congeal to be cooled artificially? How is it to be deprived of its heat? Nothing is simpler, if we only understand how to

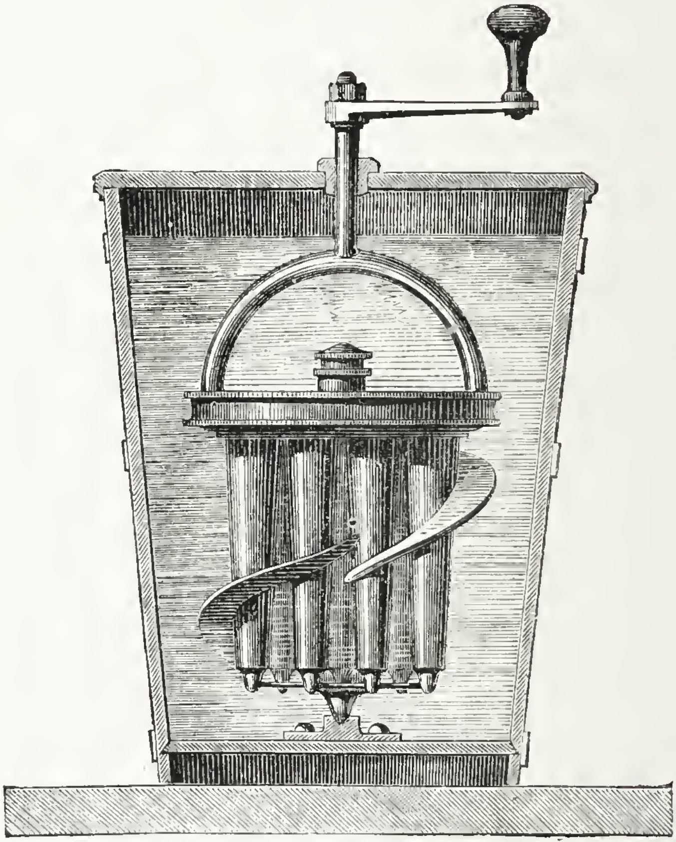

FIG. 45.

apply certain physical laws. It is well known that when a body passes from a solid into a liquid, or from a liquid into a gaseous state, it generally absorbs heat, and thus cools whatever may be in contact with it. If you throw a drop of ether on your hand the liquid will rapidly evaporate, and pass from the liquid to the gaseous state; but by the act of evaporation the ether absorbs heat from your hand and leaves a strong sensation of cold. If you throw a handful of nitrate of ammonia into a glass of water the salt will dissolve; from a solid it passes into a liquid, and a change of temperature will accompany this transition. These simple experiments contain the principles of the refrigerating apparatus.

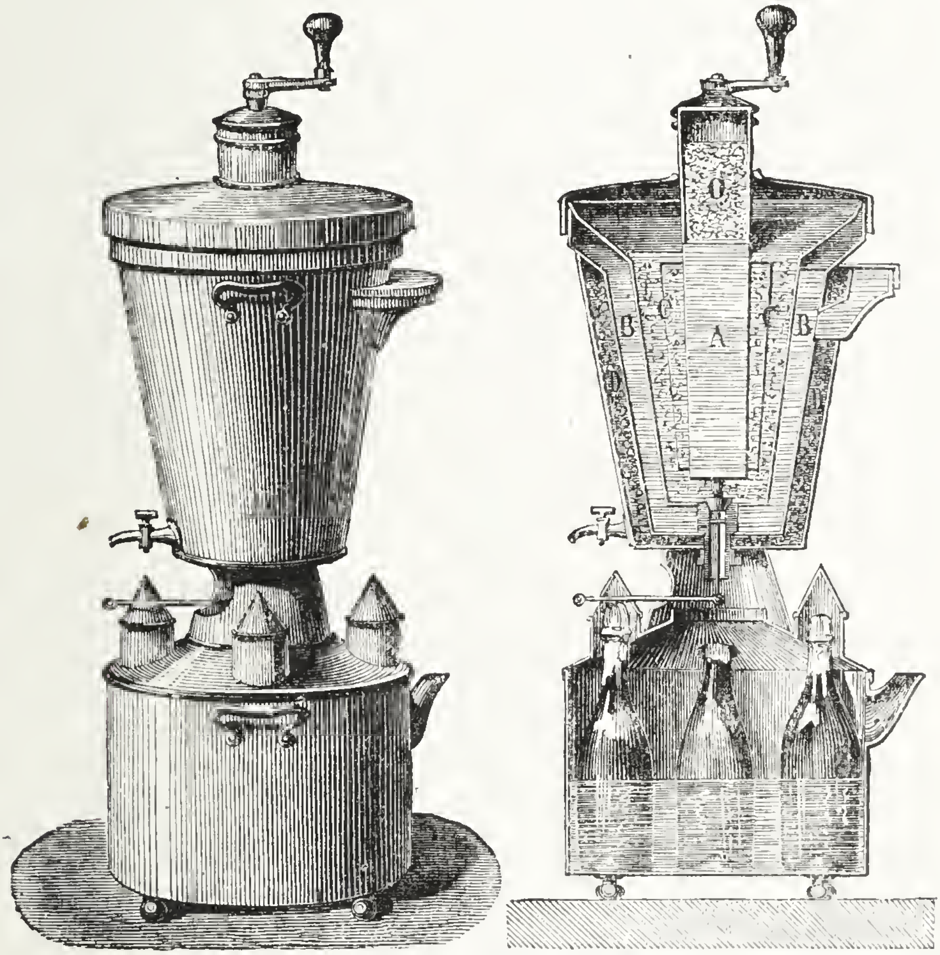

FIG. 46.

Fig. 45 shows a system of cylinders arranged in a wooden vessel so as to revolve by turning round a handle. Into these cylinders we pour the water which is to be congealed. The external vessel is full of water, into which we throw a few pounds of nitrate of ammonia. The salt in dissolving absorbs heat from the cylinders with which the solution is in contact, and from the water which they contain. If now we turn the handle so as to make the salt dissolve rapidly by the agitation of the spiral palettes, we shall presently find blocks of ice in the cylinders originally filled with water.

On a similar principle household refrigerators are made (Fig. 46.) A cylinder A filled with water to be frozen is surrounded by a refrigerating mixture; * the cylinder being turned round by the handle, the water it contains is speedily transformed into ice; at the lower part of the apparatus a valve which is opened by means of a small lever permits the escape of the water from the freezing mixture. This water falls into a basin in which are placed the bottles of wine to be cooled.

* There are various compositions which may be made use of in preparing a refrigerating mixture:—

	PARTS.	LOWERING OF TEMPERATURE.
Sea Salt . . .	1	from + 10° to − 12°.
Pounded Ice . .	1	
Water . . .	10	from + 10° to − 16°.
Salammoniac . .	5	
Saltpetre . . .	7	
Water . . .	1	from + 10° to − 10°.
Nitrate of Ammonia .	1	
Sulphate of Soda .	8	from + 10° to − 17°.
Hydrochloric Acid .	5	

The employment of acids is always disagreeable or dangerous, and should if possible be avoided. Nitrate of ammonia is preferable. When the solution is no longer cold it may be evaporated, and thus the salt is reproduced, and will serve again on another occasion.

Carré's Freezing Apparatus.

This machine consists of a cylinder in communication by means of tubes with a vessel in the form of a truncated cone, having a cavity in the centre. This apparatus, hermetically closed, is furnished with a thermometer which indicates the temperature of the interior of the cylinder. We first heat the cylinder, while the conical vessel is plunged into cold water; in the central cavity of the conical vessel is placed a metallic cylinder filled with water. When the thermometer reaches 130° the stove is replaced by a vessel of water, the conical vessel is sensibly cooled, and we are soon able to take from the cavity a block of ice.

Ice is thus produced by means of coal, and the apparatus can be used over and over again without any change. It is sufficient to heat anew the large cylinder.

But how does this apparatus act? Its mechanism is extremely simple. The cylinder contains ammoniacal gas dissolved in water. When the water is heated the gas escapes from the liquid, and passes into the conical receiver through the connecting tubes. But on arriving there it finds no outlet, and the heat continually expelling from the water fresh quantities of gas, the ammonia becomes liquefied in the conical vessel. The generating cylinder is then plunged into cold water, and, when thus chilled, the water in the cylinder is capable of receiving back the ammoniacal gas. The gas which is liquefied in the conical receiver returns to the gaseous state, and the change is accompanied by an absorption of heat at the expense of the water contained in the central cavity of the receiver. The water thus cooled is turned into ice. It may thus be seen how simple is this apparatus, and how ingenious is its mechanism, which is far preferable to any previous method. It is still, however, capable of improvement, as its inventor, M. Carré, has himself proved. The small dimensions of the apparatus prevent its furnishing large quantities of ice at a time; it does not act continuously, and could never be of much commercial value. Another apparatus, which acts continuously, has been constructed on a much larger scale, and has successfully solved the important problem of the artificial formation of ice. A large boiler A (Fig. 47) contains the solution of ammonia. The gas escapes and becomes liquefied in a receiver (B), which is kept cool by the water which falls from a reservoir (C). The liquid ammonia penetrates into the hollow sides of the refrigerator (G), in which are placed cylinders filled with water to be congealed. A special arrangement permits the exhausted water of the boiler, after being cooled, to penetrate into a vessel (E) put in communication with the cylinder (D), into which is distilled the ammonia volatilised in the refrigerator. The original liquid thus regenerated is reconveyed into the boiler by means of a pump (F).* This apparatus acts with great regularity, and it is astonishing to see the blocks of ice issuing from this refrigerator, which are formed as if by magic, without any visible agent to divulge the secret of their formation.

* A complete description of the numerous parts of this apparatus requires a voluminous explanation, on which we cannot enter. Further details may be found in the Report of M. Paulett in the "Bulletin of the Society of Encouragement, 1863."

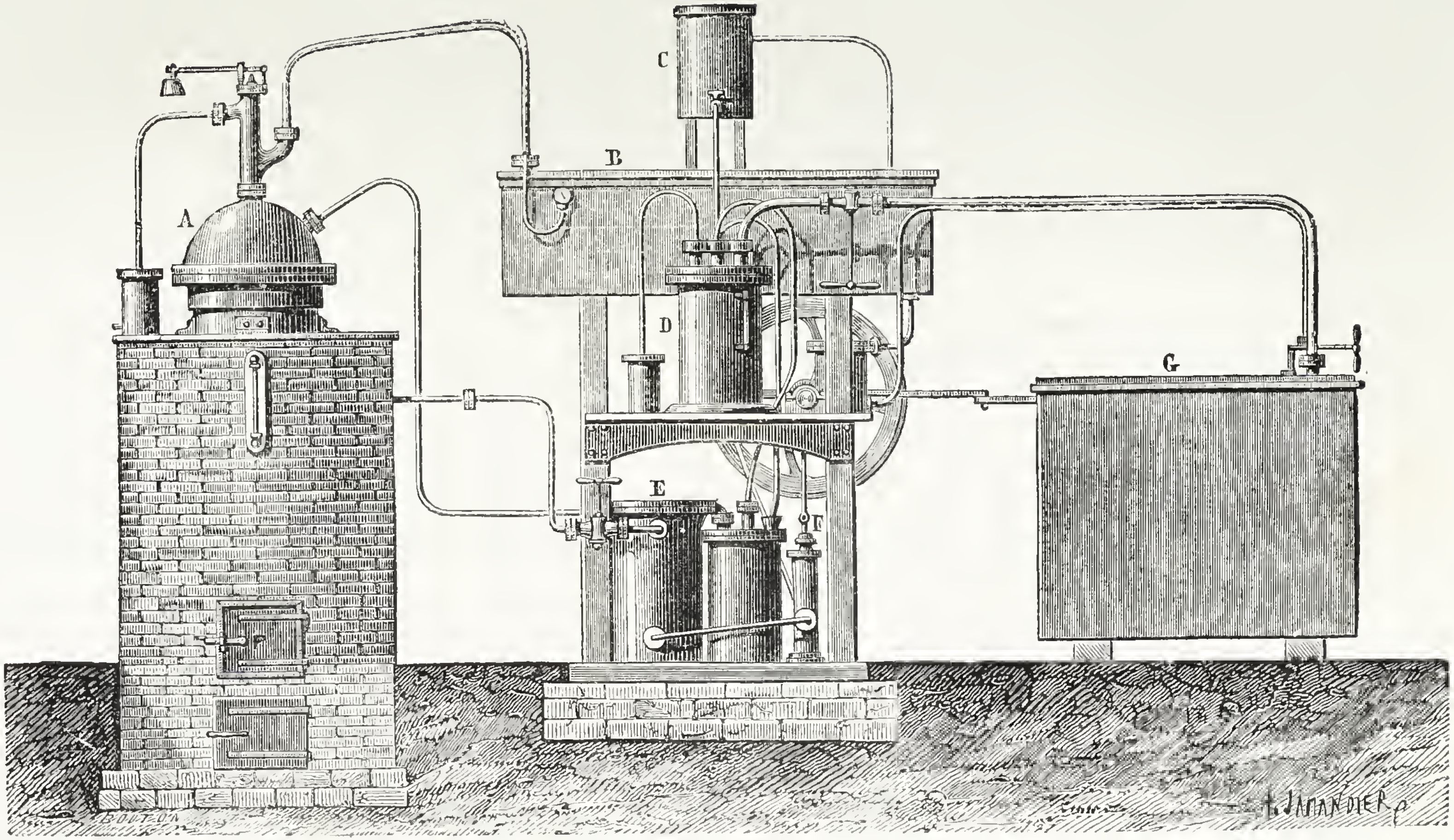

FIG. 47.

CHAPTER IV.

MINERAL WATERS.

Popular Errors.

NOTHING has more exercised the talents of inventors of incredible stories than the origin of spring and mineral waters. The reader can judge of this from some miraculous occurrences narrated by ancient authors.

According to Theophrastus, the water of the Crathis turned the animals white which drank of it. According to Ovid, Vibius Sequester, and Antigonus, the waters of the Sybaris dyed the hair a golden yellow.

> Electro similes faciunt auroque capillos.
>
> OVID.

Shepherds who wished to have white sheep led them to drink from the river Aliacmon, while those who desired them to be black or brown made them quench their thirst in the Axius. In Bœotia, near the temple of Trophonius, there existed, by the river Orchomenus, two fountains, of which one had the power of quickening the memory, while the other destroyed it. One was called Mnemosyne, the other Lethe.

Varro states that near Cessus there ran a brook named Nous (the Greek word for intelligence), which faculty its waters gave to the mind; while there was in the Island of Cos a spring which rendered him who drank of it stupid. There was another at Zama which endowed the human voice with admirable force and tone. The water of Lyncestius, in Thrace, caused a gentle intoxication; while, on the contrary, according to Eudoxus, the water of Clitorium gave a distaste for wine. Theopompus also cites a great number of examples of intoxicating water. Mucien goes still further; he seriously affirms that in the Isle of Andros a fountain consecrated to Bacchus furnished real wine at certain seasons of the year. At Cyzique the fountain of Cupid cured love. Crésias states, and Antigonus confirms the fact, that there existed in India a pool on the surface of which nothing, not even a dead leaf, could float. Perjurers could not endure the waters of Olachus, in Bithynia; they were burnt therein as in boiling oil. In Thrace certain waters proved instantaneous death to those who drank of them. If we believe Vibius Sequester, a person who bathed several times in Lake Triton, in Thrace, would become metamorphosed into a bird. The inhabitants of Lycia, according to Pliny, consulted the fountain of Limyra on the subject of future events, by throwing food to the fish which dwelt there. When the response was favourable the fish eagerly seized their prey; but if otherwise, they pushed aside with their tails whatever was offered them.

At Colophon there was a fountain which endued with divining faculties all who drank of it, but at the same time shortened the period of their life. This fountain was situated in a cavern consecrated to Apollo, and Tacitus tells us that it was there Germanicus received the prophetic intimation of his premature death.

The springs of Hippocrene and Castalia inspired poets. The fountain of Diodone revealed the future by the soft murmur of its waters; and an aged priestess, constantly seated on its banks, comprehended and could translate its mysterious language.

The fountain of Patras furnished certain prognostics on the subject of diseases. A mirror was placed on the surface of the water, and after an invocation to the deities the image of the sick person appeared, and was beheld dead or alive, according to the turn which his malady had taken. The fountain of Apone, near Padua, enjoyed a great renown among the ancients, who consulted it frequently. Playing dice used to be thrown into its transparent waters, and the side uppermost furnished the answer.

It is not only from the records of ancient Greece and Italy that we may borrow these superstitious legends. mediæval tradition and the folk-lore of every time and country abound in similar beliefs concerning the healing efficacy of certain waters. A great number of them are still perpetuated even among us; and the ignorant peasantry of many countries tell you various tales on the subject, of which they are very unwilling to reject the authenticity; but the pure waters of our fountains and mirror-like lakes conceal no such mysteries.

Farewell, then, lovely naiads, timid nymphs, who formerly concealed yourselves among the reeds. Farewell, charming divinities of the waves, we shall never behold you more. Touching poetry of fables, ingenious dreams of imagination, your reign has passed away for ever.

The Action of Mineral Waters.

To exaggerated credulity succeeds an equally exaggerated scepticism. After having too easily admitted the most marvellous statements, we become apt to ignore altogether the beneficial action of mineral waters. In our own days, however, more reasonable opinions have gained ground, and no one at present doubts the efficacy of mineral springs in healing a great number of maladies. It is, however, a very generally prevailing opinion, and perhaps a just one, that the efficacy of the waters is due in great measure to the beneficial influence of a pleasant journey, and to the salubrity of the country, in which health may be as contagious as sickness is elsewhere. But making every allowance for other influences besides those produced by the mineral waters, it must still be conceded that certain waters have a real effect, an effect attested by animals themselves, who cannot be affected by delusions of the imagination.

How do mineral waters act? Doubtless through the salts which they contain; but on this delicate subject there prevails much uncertainty. The analysis of mineral water is a difficult problem for the chemist to solve. He may find a number of different chemical elements in the water; but how are these principles united among themselves? It is this which cannot be certainly known. We have, indeed, in our hands the disjointed materials of the building; but how are these materials associated and grouped together? If we knew the proximate composition, would we not find that there existed between a medicinal water and the principles it contains a relation which permits its properties to be deduced beforehand? It is not so, however, and observation frequently differs from the deductions of theory. There scarcely exists any constant connection between the chemical analysis of a spring and its effects upon health. Mineral waters act by feeble doses; they are homœopathic remedies.

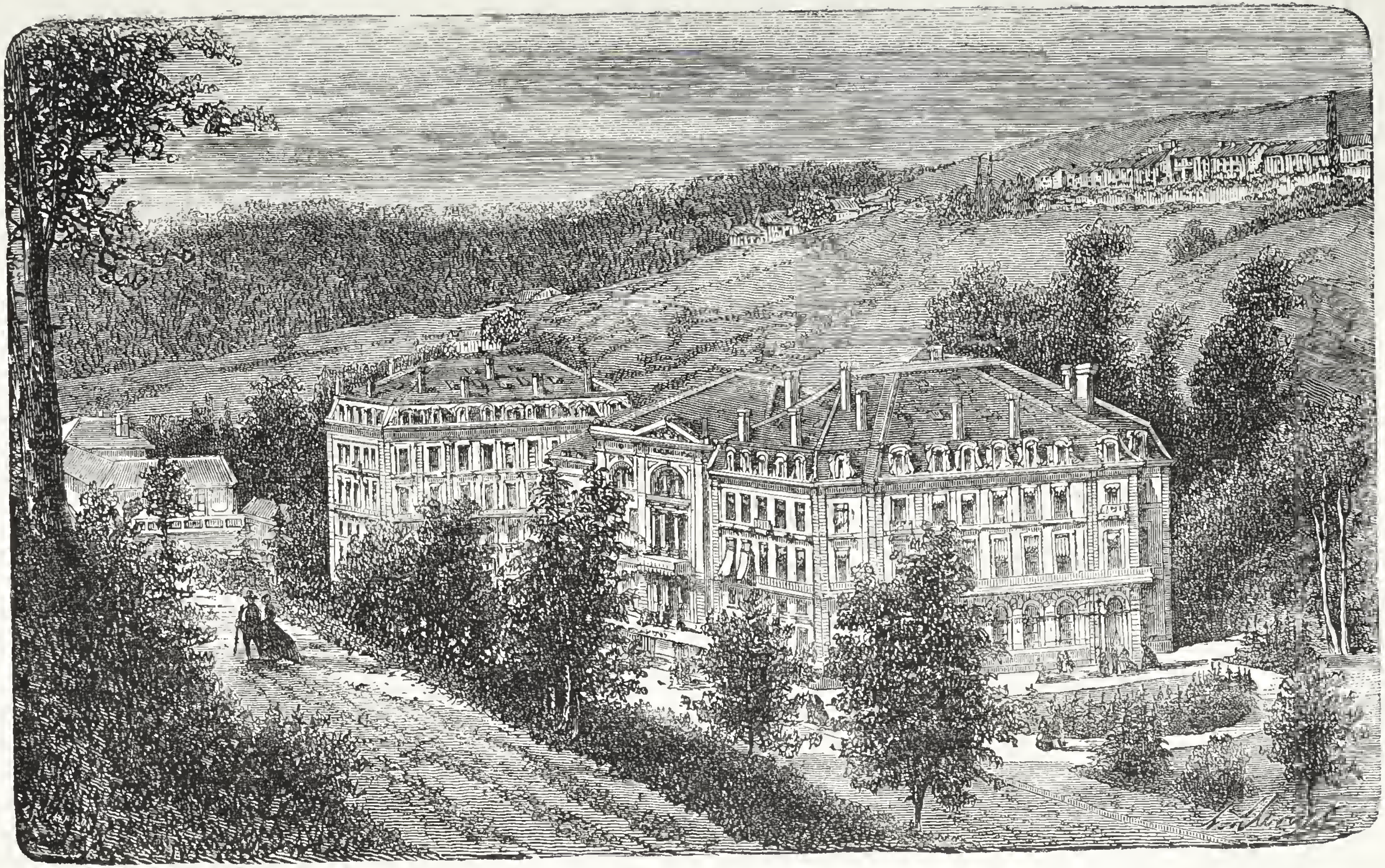

FIG. 48.—PLOMBIÈRES.

the action of which escapes the most careful enquiry. Their composition is, moreover, not yet very well understood, because they generally contain traces of organic substances which chemists have not been able to study. A mineral spring contains, perhaps, a proportion of one part of iron to twenty thousand parts of water, and yet acts with

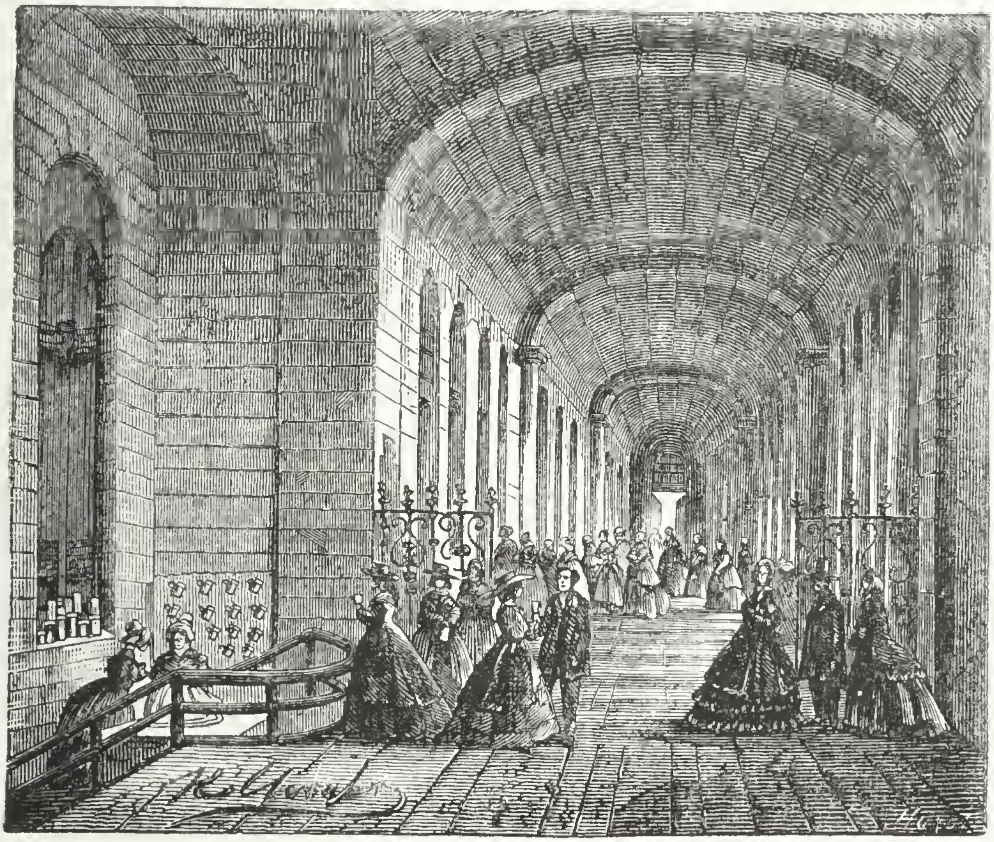

FIG. 49.—BATH ROOM AT VICHY.

more efficacy than all artificial medicines. Frequently when physicians find medicines fail, they see unexpected effects produced by mineral waters.

There is in rich springs something more than the mineral held in solution, there is organic matter often in considerable quantity. This has been usually ignored, but we believe very erroneously, as the therapeutic efficacy may, perhaps, be due to the presence of this ingredient. "A mineral water," as Dr. Constantine James has well observed, "is not an ordinary saline solution; it is a special drink which has its own element, its special flavour, which nature has fabricated by its own chemistry, of which she has hitherto preserved the secret."

There are four different classes of mineral waters. 1. Gaseous water, which contains carbonic water in solution. These waters may also contain some salts of lime and magnesia, and a little iron. Such waters are found in Seltz, Ems, and Wiesbaden. 2. Saline waters, such as those of Plombières and Vichy. 3. Iron waters, such as those of Spa. 4. Sulphur waters.

In the country of the Mormons there exists a remarkable sulphur spring, so warm that it is always boiling, and throws into the air clouds of smoke. The celebrated water of Barèges contains only a small quantity of sulphate of sodium; this water is useful as a remedy for sprains, incompletely healed sores, and stiffenings of the joints. It is reputed to be of sovereign efficacy in the treatment of old wounds.

The renown of the water of Barèges is due to Madame de Maintenon, who brought the Duc de Maine thither in 1675. The young prince was of a delicate constitution, and the sulphur waters renewed his health. It was the celebrated physician Fagon who discovered the baths of Barèges, which up to that time had only been frequented by a few peasants.

Treatment.

"When you arrive at the waters," says Alibert, "act as you would do if you were entering the temple of Esculapius, and leave behind you at the door all the passions which have been troubling your mind and agitating you. Once there abstain from imprudence, and do not exceed the prescribed doses, as so many invalids have done at all times, since the days in which Pliny wrote. Many sick people take a pride in having remained for hours together in very hot baths, or drinking unmeasured quantities of mineral water, which are both equally dangerous. Lead a quiet, calm, tranquil life, bathe and drink with moderation, and the water will gradually exercise its beneficial influence upon you, your sufferings will insensibly pass away by the precious liquid, and your frame will become invigorated."

Formerly invalids sent by their medical attendants to the waters, were made to undergo a severe preliminary treatment. The illustrious Boileau gives an account of this in a letter written to Racine. "I have been purged and bled," writes the author of "L'Art Poétique," "and nothing more remains for me to undergo of the formalities considered necessary before taking the waters. The medicines which I have taken to-day have, as they tell me, done me all the good in the world, for they have caused me to fall down four or five times from weakness, and have thrown me into a state in which I can hardly stand upright. To-morrow I am to begin the great work. I mean to say that to-morrow I am to begin taking the waters."

Happily our physicians no longer resemble the contemporaries of Boileau, the class which Molière describes; and the cures due to mineral waters are more frequent and complete.

Let us be grateful to the admirable natural medicines which are able to procure us that greatest of all blessings, health. "A most precious possession," says Montaigne, "and the only one which deserves all that is expended upon it, not only of time, wealth, and fatigue, but also life itself if it be necessary to sacrifice life in its pursuit; for without health life is painful and distressing; without health pleasure, wisdom, science, and virtue would languish, and at length perish."

CHAPTER V.

BATHS.

THE celebrated Medea, who in the time of the Argonauts astonished all Greece by the prodigies which the art of magic enabled her to accomplish, owed a part of her success to the power she claimed of making the old young. According to Piléphates and other ancient authors, she attained these marvellous results by the use of baths of mineral waters, of which she understood the properties.

From the days of Homer, who represents his heroes as bathing in vast fishponds, to those of the contemporaries of the fall of the Roman Empire, when all the appliances of an unbridled luxury might be found in the *thermæ*, the use of baths has played an important part among the customs of antiquity. The reader will doubtless remember the *piscinæ* of the Spartans, and the baths of Athens, of which Lucian has given so complete a description. Much also has been written concerning the baths and *thermæ* of the Romans, Latin writers making frequent allusions to them, and well-preserved vestiges of *thermæ* are still existing at Pompeii. Seneca and Lucian still awaken our astonishment by the descriptions they give of the refinements of luxury which were to be found in these public establishments. None of the entrances were direct, the bathers being thus screened from contact with the air, and such other inconveniences as the proximity to the open street might bring. Two doors conducted you to the *atrium*, surrounded with graceful coloured porticoes, in which the numerous bathers could comfortably await their turn for entering the bath. From the atrium you went into the hall called the *spoliatarium* or *apodyterium*, in which the slaves, *casparii*, disrobed the bathers, and kept watch over their clothes and valuables. An adjoining apartment, the *unctuarium*, was devoted to perfuming the body by means of oils and aromatic essences.

We should never have finished our description if we were to enumerate all the arrangements which an immoderate love of luxury and comfort had suggested in these baths, if we had to elaborate every detail in connection with the *frigidarium*, or chamber of cold baths; the *baptisterium*, a piscina of white marble, furnished with rows of seats on which the bathers sat; the *tepidarium*, a heated apartment kept at a gentle temperature; the heat-conducting pipes arranged beneath the pavement; the *labrum*, a sort of marble vase which contained water to wash the hands and face of the bather who had been perspiring in the vapour-bath.

"A complete bath," says Galen, "is composed of four parts each different in its effects. When you enter the thermæ you are subjected to the influence of hot air, you are then wetted with warm water; after that you plunge into cold water, and last of all you are dried and rubbed." The routine which Galen indicates must frequently have been changed by the caprices of fashion, and it is now impossible to describe exactly the various processes of shampooing and anointing, which were multiplied at pleasure by the effeminate descendants of the Romans of the republic. Publius Victor, in the fourth century, counted in Rome no less than nine hundred bath establishments; and the number was still on the increase, when the advancing progress of Christianity came in to stop a practice which had passed from the domain of hygiene to voluptuous self-indulgence. In spite, however, of the opinion of Agathinius, the pupil of Athenæus, who saw in the use of warm baths a thousand evils and dangers, the use of baths had followed the development of Roman society, and could only perish with it.

Doomed for generations to lie under complete and general disrepute, the use of the bath revived in the age of Charlemagne. Popular tradition shows us the Emperor of the West bathing with his whole court in the piscina of Aix-la-Chapelle. If we are to believe the legend, it is to a hunting dog that we owe the use of mineral waters. The intelligent animal having escaped from the royal pack of hounds to bathe in a distant spring, returned dripping with a liquid smelling strongly of sulphur. The dog thus suggested the use of a fountain which had never before been employed.

But it is not alone either in ancient or in modern Europe that the use of the bath may be found. The oriental nations, the Indians, savages of all countries, frequently made use of baths. During the sanguinary wars which the Moors maintained against the Christians, the Moors were accustomed to plunge into any stream they might meet with, and are said to have derived signal benefits from the practice.

Averrhoës recommends vapour baths, and expresses his opinion strongly on the value of their medical use. Alibert gives us the translation of a passage taken from the "Medical Observations" of the ancient Emperor Kang-Hi, a passage which leads to the supposition that the qualities of mineral waters must have been long understood in China. "Nothing is truer," says the royal author, "than that thermal waters are efficacious in the treatment of various diseases." In 1691 this emperor undertook a long journey for the purpose of visiting and spending several months in a district situated to the north of Pekin, and celebrated for its beneficial baths of natural waters.

The Esquimaux, the Fins, the Greenlanders, the Norwegians, make use of vapour baths, constructed, it is true, upon a plan the most simple. A hole scooped in the earth, some pebbles made red-hot at the fire, form the bath and the stove. The bathers enter the hole, and the steam which is caused by the moisture of the soil when warmed by the hot pebbles constitutes the vapour bath. The missionary Loskiel describes analogous practices among the North American Indians.

In our own day every nation has a different method of taking the bath. The Russian practice is, after a very hot vapour bath to plunge into a shower bath of cold water. In the east both hot and cold baths are alternated; but in all countries, simple immersion and the douche bath are most frequently in use.

Besides the local action of baths, besides the absorption of considerable portions of water by the human body, we are compelled to admit that baths act medicinally by the substances which they contain. Those waters which hold in solution a perceptible quantity of organic matter, produce upon the skin a soft and unctuous sensation, which refreshes and invigorates the frame. Sulphur waters containing soda act as excitants, and produce a beneficial effect upon the surface of the skin. Warm baths impart to the bather a feeling of strength, and at the same time of comfort; while fresh water, and still more sea water baths, can only be used by constitutions capable of resisting their depressing influence. But is there not much in the ordinary use of baths with which fault may be found? If the Romans abused the bath, may it not be said of us moderns that we do not make sufficient use of it? Where are the magnificent thermæ, the piscinæ, full of bathers at every hour of the day? They have been replaced by a narrow cell in a miserable bath house. The perfumes and aromatic oils have disappeared, and there is now to be found in a bath house neither a couch to rest on nor appliances for shampooing. Where are those halls so spacious and so well warmed and ventilated, where the bather could dry himself gradually before encountering the external air? In all baths of the present day the bather is exposed to a sudden, and consequently dangerous, transition from the heat of the water to the cold of the external air.

Fresh and Sea Water Baths.

All medical authorities are agreed in recommending the use of cold baths, and the inhabitants of Paris have always been accustomed to bathe in the cool waters of their river during the heats of summer. In the country, when the sun is darting his burning rays upon the earth, the bather finds a delicious coolness in the waters of the river, where, allowing himself to be cradled by the waves, and following a track shaded by tufted willows, he swims along the health-giving current, his pores eagerly absorbing the liquid.

The first plunge in the sea is usually unpleasant, but the comfort soon experienced causes the disagreeable sensation to be forgotten. Swimming is so easy, and the expenditure of muscular force so inappreciable, that the bather is tempted to prolong so pleasant an exercise. Its duration, however, has to be carefully regulated, for the circulation slackened, or even partially suspended, does not soon recover its normal condition if the bath has lasted long. When we leave the water a reaction takes place; the skin resumes its former colour, the blood circulates freely, and the beating of the heart becomes more vigorous.

To use the language of Galen, uttered more than a thousand years ago, "Experience itself can be our only guide as to how long it is advisable to remain in the water. If, when we come out of our bath, the skin soon returns, by rubbing, to its natural healthy colour, we have remained in the water a proper time, but if it takes a long time for our skin to become warm again and to regain its colour, we see a sure indication that our bath has been too prolonged."

Sea water is a true mineral water. Marvellously rich in saline principles, it is a vital spring from whence the feeble may draw strength, and sufferers from every species of ailment may draw health. In its bosom lie hidden many remedies, many most valuable medicines. "We should," says Russel, "both drink sea water and bathe in it." In the sea we find carbonate of lime, which can give strength to our weakened bodies; iodine, which purifies our blood.

"Whatever principles," says Michelet, "exist in you, the sea, that grand impersonal personality, possesses in herself; she has in her your bones, your blood, your vital warmth. But she possesses what you have not, the excess, the overplus of force. Her breath imparts a mysterious

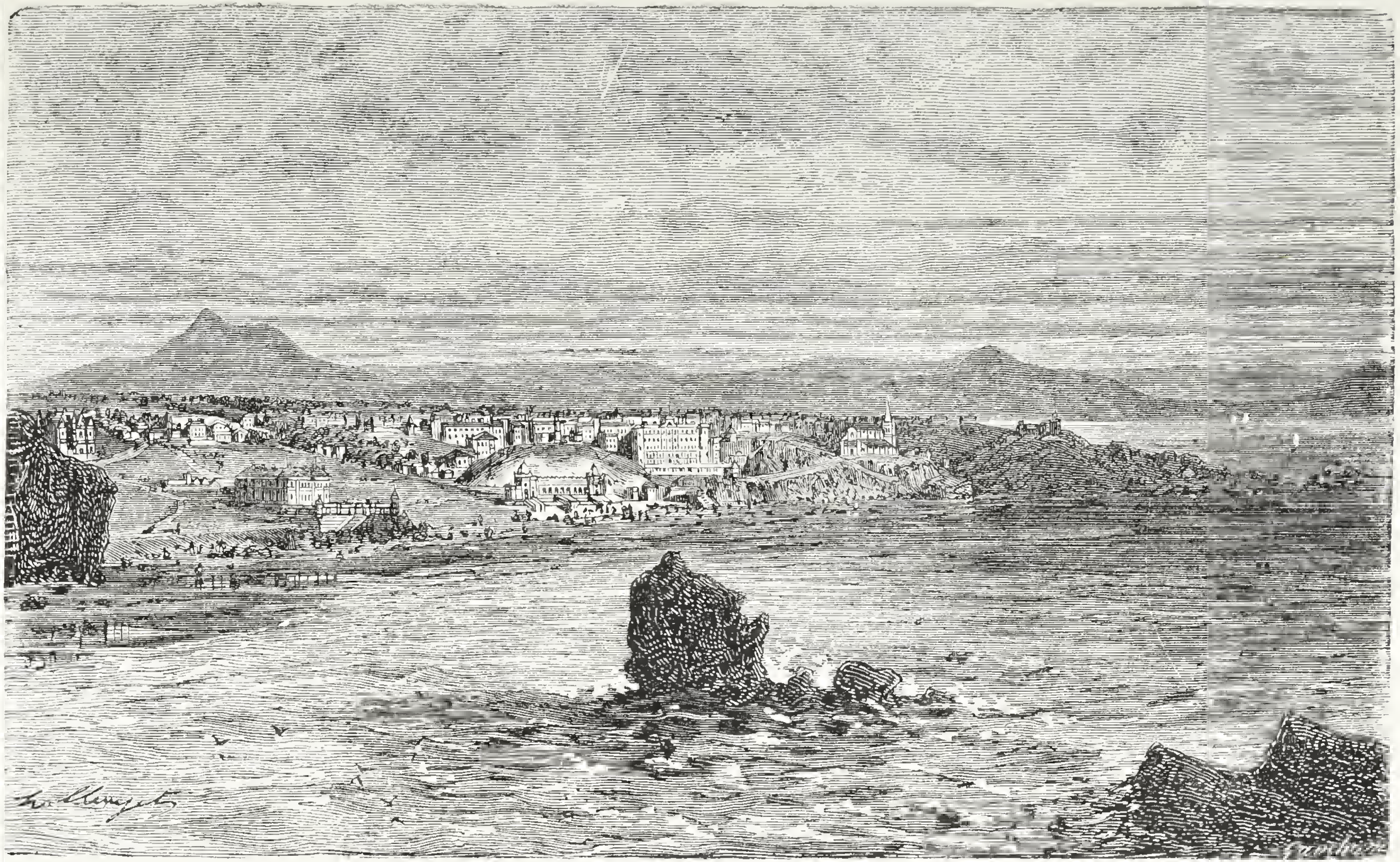

FIG. 50.—BIARRITZ.

something of gaiety, of activity, of creative energy, which one may term a *physical heroism.* With all her violence, the great ocean is none the less prodigal of that joy, that lively and quickening alacrity, that wild and burning love, which animates herself."

The Water-cure.

There exists in Germany a celebrated school of medicine which affects to cure all diseases by the mere use of water. Cold water for the healing of wounds, thermal and mineral waters, ice and snow waters, are all utilised; these, we are told, are the only weapons which physicians should make use of for combating the evils to which flesh is heir. Water is thus transformed into a universal panacea. It is no doubt the disciples of this school who have ascribed a German origin to the water-cure, a most important branch of the healing art, which has, however, nothing really new about it but the name.

Has not Seneca shown us the effect of cold water in restoring the sick person from syncope? Does not Horace show us Patroclus washing the wound of Eripyles with cold water? Have we forgotten Hecuba's cries for water to wash the wounds of Polyxene? Do not these facts prove that the ancients employed water as a healing agent? Douche-baths were certainly known to them, and it was at Rome, in the reign of Augustus, that hydropathic practice had its birth, under the happy inspiration of a freedman—Antonius Musa. This physician prescribed water as a drink, in baths, and in douches; and he found in this remedy, simple as it was, the secret of a new system of therapeutics. Augustus had only lately been elected Consul for the eleventh time when he fell ill with a dangerous sickness. Feeling his end approaching, he assembled the magistrates, the senators, and the principal knights, and then, having conferred with them on the affairs of the republic, he placed the seal of the empire into the hands of Agrippa. It was then that Antonius Musa undertook to cure him by a new method, and succeeded by means of cold water applied both internally and externally. Augustus, full of gratitude, bestowed on Musa a large sum of money and a gold ring, and had a statue raised to him and placed beside that of Esculapius; also conceding to him, and to whoever then exercised and hereafter should exercise the same profession, nobility and the exemption from payment of taxes (See Dion Cassius, quoted in Dr. C. James's "Guide to Mineral Waters"). Musa was not long in acquiring a universal reputation. "Ah Musa!" cried Virgil, "no one may flatter himself that he will ever surpass thee in science." Hydropathy was already superseding every other branch of therapeutics. Horace himself had recourse to this famous physician, and the graceful poet, after having sung the praises of Falernian, sought the virtues of cold water. Horace set out for Velia, where Musa prescribed for him a hydropathic treatment, and afterwards took sulphur-baths at Baii.

Fortune was not always prodigal of her favours to the celebrated Musa. Being called in to attend the young Marcellus, whose life was in danger, he determined on having recourse to his favourite system; he recommended cold water, and Marcellus sunk. This event was a terrible blow both to hydropathy and to its inventor. The cold-water-cure was universally discredited. A century later, Charmis, under Nero, recommenced the system of Musa. It again met with the same success and awakened the same enthusiasm; cold baths again grew the fashion, and were taken at all hours of the day. Nero was in the habit of adding snow to the water of these baths.

Charmis, says Dr. James, like Musa, prescribed cold water internally as well as externally, and that in large doses. It was needful, according to Pliny, to drink before you sat down to table, during the repast, and again before going to sleep. It was even necessary sometimes to be awakened in order to drink again—*et si libeat somnos interrumpere.* The temperature of the water could never be too low. The impulse given by Charmis was continued long after his death. Celsus, who survived him, and the successors of Celsus, frequently prescribed cold water, and we may see in their writings the successful applications which they made of it in the treatment of the sick. Little by little warm baths superseded cold ones; so much so that in our own day the latter had become entirely abandoned, when suddenly their use received a new impulse from Priessnitz, from whom the dawn of modern hydropathy may be dated.

In 1816 a peasant of Silesia, named Priessnitz, was returning home from the fields, when a horse, which had run away and was rearing, struck Priessnitz in the face, and broke one of his ribs. There being no doctor in the little village of Freiwaldau, Priessnitz determined upon doctoring himself. He caused his broken ribs to resume their proper position by constantly leaning his chest against the corner of a chair. Instead of bandages, he made use of a wet rag, he drank freely of cold water, and was soon able to return to his work.

This cure made a great sensation, and Priessnitz was ere long consulted on all cases of sickness. He applied far and wide his cold-water system, and being of an observing turn of mind he tried to supply by observation what he lacked of scientific knowledge. He travelled from village to village, treating all who applied to him for help, and acquiring a name which gradually became famous. Some years after, Priessnitz had founded a vast establishment, to which flocked a crowd of invalids from all parts of the world, seeking from empirical art that healing which medicine was unable to bestow on them.

Hydropathy was very tardily received at Paris, and a steady opposition to it was maintained for a long time. But little by little our citizens grew accustomed to the new treatment, and cold baths, cold water douches, and applications of ice are employed by most of our doctors.

In what consisted the method of Priessnitz? Cold water drunk freely, wet wraps, cold baths, rubbings with a damp cloth, cold shower-baths, cold plunging baths, cold foot baths—such were the only prescriptions of the old Silesian peasant. These methods are excellent in certain cases, and hydropathy is without doubt one of the important branches of the healing art. But this new method has been injured by its too zealous advocates, who have absurdly over-praised it and decried all other systems.

Artificial Mineral Waters.

The idea of replacing mineral waters by similar waters artificially produced is very ancient, and several of Galen's contemporaries endeavoured to prepare beverages which should rival the most vaunted springs. But in the opinion of Herodotus no beverage of this description equalled the water from which it borrowed the name, and numerous attempts have proved that Herodotus was not far wrong. Many kinds of mineral water, of incontestable efficacy, have

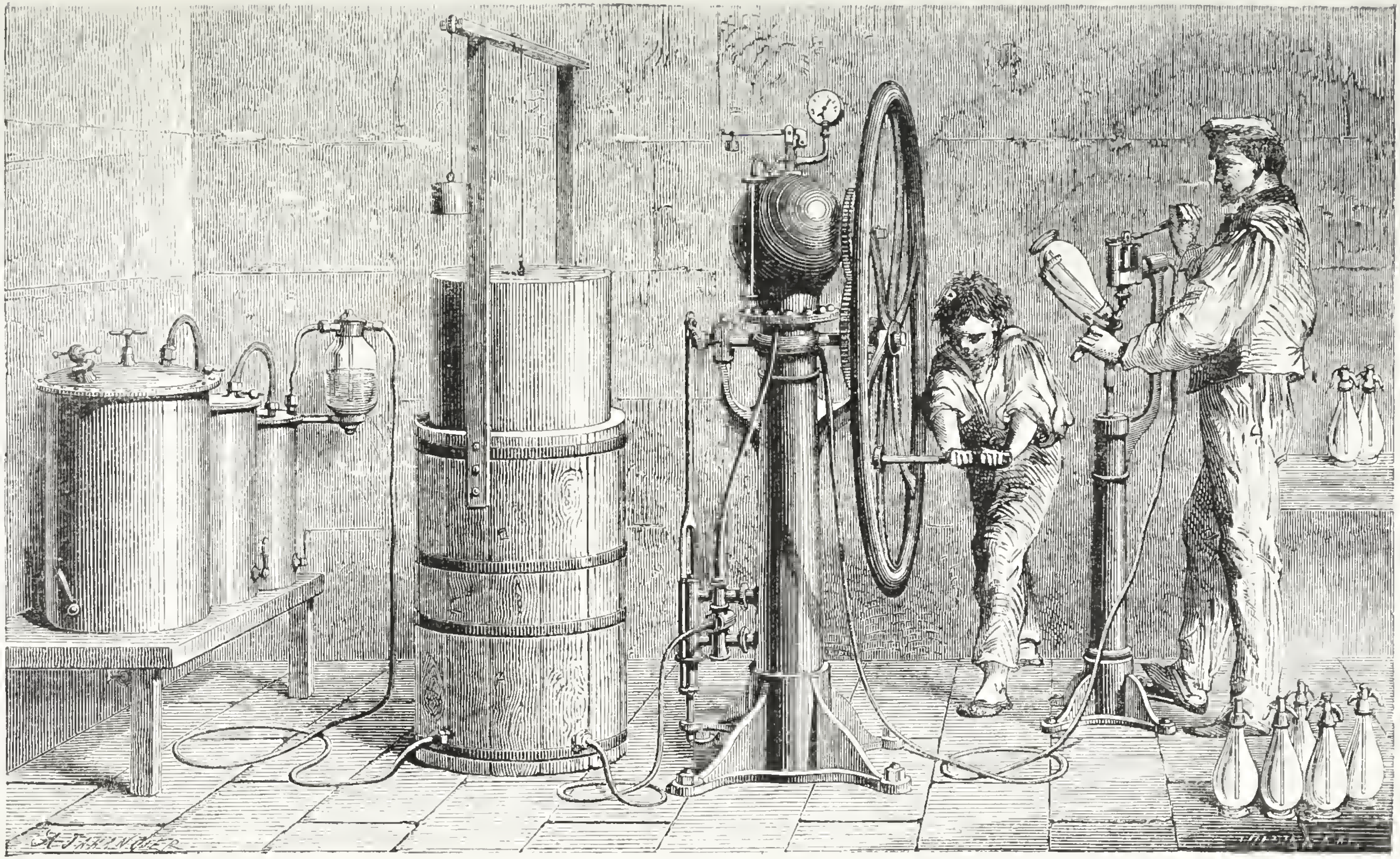

FIG. 51.—SELTZER WATER APPARATUS.

indeed been manufactured, but there is little affinity between them and those which nature has produced in the bosom of the globe. The Sedlitz water of chemists is merely suffered by courtesy to have any analogy with that of the German spring, and the ordinary Seltzer water drunk at meals does not really resemble in the least that which is supplied by the celebrated fountain in the duchy of Nassau. It is, however, a very wholesome and refreshing beverage, so universally held in repute that it will be well to describe its preparation.

Seltzer water is simply common water charged with carbonic acid by high pressure, and is prepared on a large scale by means of the apparatus which we have represented in Fig. 51. The carbonic acid gas, which is produced in a metal cylinder by the action of sulphuric acid upon carbonate of lime, chalk, marble, etc., traverses three purifying vessels, and then is received into a gas-holder. A pump compresses the gas into a spherical receiver, furnished with a pressure-gauge, and a leaden tube conveys the gas into the bottle under a pressure of ten or twelve atmospheres.

CHAPTER VI.

PUBLIC HEALTH.

Drinking Water.

THE traveller who explores, at the cost of fatigue and hardship, those remote countries which are entirely deficient in water; the explorer who, lost in the burning sands of the desert, lacks even the drop of water which might cool his burning thirst, know well how to appreciate the blessings of this precious liquid. If you read the travels of Vambéry in Central Asia, you will see what suffering want of water caused to this enterprising traveller. You will see how a generous man was rendered so selfish by suffering as to refuse to those whom he saw dying before his eyes a few drops of stagnant water. Under ordinary circumstances each man absorbs three and a half pints of water a day. A lesser quantity would cause real physical suffering. It may be imagined, therefore, what a great influence the salts, which water holds in solution, even in small quantities, must exercise over the animal economy. It is necessary that the water be wholesome and of good quality. Opinion, in every age, has attributed to the action of bad water certain endemic diseases, and though such opinions may have been exaggerated, it is none the less true that some waters are highly deleterious. It is easy to understand, on the same principle, how waters containing salts favourable to the animal economy, and holding in solution gaseous products calculated to facilitate digestion, become, through daily use, the surest, most precious, and most valuable agents of health.

Fresh waters may be divided into rain water, spring water, the water of rivers, that of lakes, that of ponds, and that of wells.

Rain water, at the time when collected, is not absolutely pure, but is the purest to be found in nature. It has, however, the defect of not holding any calcareous matter in solution. It is insipid and of a sickly sweet taste. The water of ponds and pools rich in decomposing organic matter has an odour so disagreeable as to banish it from the table. Springs, lakes, rivers, wells, are the sources of the water we drink ; but the ingredients of the water they contain are so different that it will be well to give a little time to the study of them, so as to find out to which preference ought to be given. Water may be considered good and wholesome when it is fresh, limpid, inodorous, not inclined to become turbid when boiled, when it leaves but little sediment by evaporating, when its taste is sweet and pleasant without being either salt or insipid, when it holds air in solution, when it dissolves soap easily, and when it boils vegetables well. The water of tanks employed in countries which are deficient in springs and rivers, does not answer these requirements, for the rain which trickles down from the roofs of houses carries along with it organic and mineral substances.

Except in rare cases, water which holds in solution a perceptible proportion of organic matter becomes soon putrid, and acquires qualities which are deleterious. Diarrhœa, dysentery, and other maladies are induced by the use of water holding decomposed organic substances either in solution or suspension. It is consequently admitted as a fact ascertained by close observation, that the less the water we drink contains of organic matter the more wholesome it will be. In certain towns, especially Cadiz, where each house possesses a cistern, care is taken to run to waste the first rain which falls from the sky, and when by means of this purification the impurities of the air, of roofs, and of spouts have been carried off, the rain which the clouds continue to pour upon the city is carefully collected.

Some well-water (the wells of Paris give a striking illustration), having traversed various strata of the earth's surface, contains large quantities of sulphate of lime; such water will not dissolve soap, nor cook vegetables, and is unwholesome. Water of this kind is detected by the abundant precipitate which it forms when a solution of oxalate of ammonia and chloride of barium is added.

The presence of carbonate of lime is necessary in good drinking water, and the experiments of M. Boussingault have proved that this substance helps in the development of our bones. But excess is always hurtful, and the so-called calcareous waters, containing, as they do, too large a quantity of lime, are unfit for drink. Water of this description becomes turbid when boiled, and leaves behind it by evaporation an abundant deposit, which produces incrustations in conduit-pipes and steam-boilers.

When water charged with carbonic acid traverses leaden pipes it becomes impregnated with the lead, and when swallowed produces diarrhœa of a serious character, and often fatal.

The water of rivers, and of some wells, only holds in solution a small quantity of chlorides, sulphates, or carbonates, with bases of lime, magnesia, soda, potash, and alumina; it is then fit for drinking; but among all descriptions of waters, that of springs is incontestably the best. "The best waters," as Hippocrates said with reason, "are those which are warm in winter and cool in summer;" and this sentence from the father of medicine, confirmed in our own days, is the opinion which ought to decide us in our selection of a water to drink.

Nothing is preferable to limpid and cool spring waters drawn from pure sources, sheltered beneath the shade of trees; and if they have become aërated by their voyage on the surface of the globe, if they have dissolved on the route which they have traversed small quantities of carbonate of lime, they offer to the thirsty a wholesome, cool, and agreeable liquid, which, contributing as it does to the health of the body, is not without influence upon our moral well-being.

Industrial and Domestic Applications.

The consumption of water may be estimated, in towns like Paris, at four gallons per diem for each inhabitant. This refers to citizens who do not follow any branch of industry which requires a large supply of water, such as that of a dyer, or brewer, or keeper of public baths and wash-houses, and who have neither domestic animals to be taken care of, horses to be watered, a carriage to be cleaned, nor a garden be attended to. If we include all classes the average consumption is ten gallons per head per diem.

We give the following table from M. J. Dupuit, the civil engineer, which will afford a general idea of the daily consumption of water in Paris.

For each person	18 quarts.
Each horse	65 ,,
Each two-wheeled vehicle	35 ,,
Each four-wheeled ditto	66 ,,
Each square yard of garden ground . . .	1 ,,
Every one-horse power of work produced by a high-pressure engine	1 ,,
Ditto by a condensing engine	9 ,,
Ditto by a low-pressure engine	18 ,,
Each bath	264 ,,

Besides these domestic and industrial uses, water has to be employed in moistening the road when the heat of the summer transforms our streets and public walks into so many sandy deserts; in cleansing gutters and kennels to obviate the dangers of stagnant water; in sewerage, and in cooling the air by means of fountains in open squares and pleasure-gardens.

All these applications are imperiously demanded by public health; but in such cases the *quality* of the water signifies but little, whether it be impregnated with gypsum or limestone, whether it be tepid or cold, it will not less thoroughly accomplish its useful mission.

Calcareous waters leave an abundant deposit, which incrusts coppers and boilers, and forms a hard and resistant coating; a stone lining is thus formed upon the metal and injures it. This lining impedes the heat from communicating itself from the furnace to the liquid within. Sometimes the metal of the boiler becomes red-hot; if the calcareous deposit then bursts, and the water comes into contact with the metallic sides of the boiler, the liquid boils with great violence, and the mass of steam which is instantaneously developed bursts the boiler, spreading death and destruction around.

Water which contains nitrate of magnesia, or chloride of magnesium, presents also serious disadvantages; these salts decompose under the influence of heat; they leave behind nitric and hydrochloric acids, which corrode the metal, and deteriorate rapidly both the boiler and all the metal pipes which they traverse.

These inconveniences are sometimes remedied by purifying the water by chemical processes. In order to prevent the incrustation of coppers, the waters are mingled with a certain kind of clay; a deposit is then made, which, instead of forming a hard crust, merely leaves a precipitate that can be easily removed.

CHAPTER VII.

THE WATER OF PARIS.

THE first inhabitants of Paris drew their water supply direct from the Seine. At a later period the Romans constructed the aqueduct of Arcueil, and the vestiges of their labours are still to be seen in the Emperor Julian's Palace of the Baths. This aqueduct perished with the Roman Empire, and it was not until the thirteenth century that the monks caused water to be obtained from the springs of Belleville and Près St. Gervais. The water thus derived would be rejected at the present day; but from it alone Paris quenched her thirst during more than four centuries (from 1200 to 1608), until the time when the pump "de la Samaritaine" was established on the Pont Neuf.

During the whole of the Middle Ages and the Renaissance period the sovereigns of France, never very solicitous for the welfare of the people, granted large monopolies to the nobles and the monasteries. The abuse became such that many portions of Paris were on the point of being abandoned, on account of the public fountains having dried up. Notwithstanding the famous edict of Charles VI. (October, 1392); notwithstanding the noble initiative taken by a provost of the merchants, who, in 1457, caused the aqueduct of Belleville to be reconstructed, favoritism still continued to triumph, and the people continued to lack water.

In 1553, Paris only received 392 cubic yards a day, equivalent to less than one quart to each inhabitant. This quantity would have scarcely sufficed a city a hundred times less populous.

When the evil had become flagrant, when the murmurs, timid as they still were, of the inhabitants reached the ear of government, when the dearth of water had become too imminent, an ordinance of the police, delivered by the provost of the merchants, abolished the monopolies. This was simply an ordinance of bad faith, which led to further monopolies and re-established things in a state more deplorable than before. There was neither order nor proper regulations, but everywhere injustice and iniquity; the great lord turning, on his own authority, the conduits of the town, before the eyes of the people, from their own humble dwellings to his mansion, where he wanted a new fountain, perhaps merely for ornament.

It was reserved for a great king to remedy the evil by energetic measures. Henry IV. at length succeeded in getting his edicts obeyed. All the pipes which conveyed the water to abbey lands and the abodes of the rich he ruthlessly cut, the minute revision of the titles of the monopolists was executed with unusual care and impartiality, and the number of monopolists was reduced to fourteen. For the first time these monopolies were obtained by purchase, and Martin Langlois, provost of the merchants, was the first who paid to the city a rent for the right of getting water from the fountain of Barre-du-Bec.

It was not in a short time that this evil could be annihilated. In 1608 the want of water again made itself felt. Henry IV. reduced the number of monopolies, and set a noble example by permitting his own to be reduced; the Fountain de la Samaritaine was erected on the Pont Neuf; and the same year saw the inauguration of an admirable project, the reconstruction of the aqueduct of Arcueil. But this work, arrested in its progress by the death of the king, was not completed till much later, under Mary de Médicis.

All things considered, the reign of Henry IV. is a page in the history of the Paris water-works which can be perused with satisfaction. It was then for the first time hydraulic pumps were made use of, for the first time also the monopolies were sold, and these important improvements are to the glory of the memory of a great king. Under Louis XIII. and Louis XIV., however, the abuses reappeared with a new and scandalous energy, and several unhealthy quarters of the city were on the eve of being abandoned. All the fountains became dry, whilst the king was spending millions of money, wrung from his people, in forming the water-works at Versailles for the amusement of his court. In 1671 a new pump, that of Notre Dame, was constructed; but notwithstanding this highly beneficial work, Paris still continued to receive only 2,354 cubic yards of water daily, or 2·6 quarts to each inhabitant.

At the commencement of the eighteenth century numerous papers, published on the subject of the Paris water supply, arrested public attention; but a few unimportant enactments were the sole results of the long and prolix discussions which were carried on upon the subject. De Parcieux, somewhat later, suggested a plan for supplying the capital from the waters of the Yvette, a little river which runs into the Seine above

Longjumeau; this plan was eagerly discussed, and public opinion then, as at the present day, hesitated between various projects, some for obtaining water from a distance, and others for endeavouring to raise water from the Seine by means of engines. In 1769 the Chevalier d'Auxiron, having suggested a new system of elevating the Seine waters by a species of engine, replied to De Parcieux. The two adversaries became involved in warm and eager discussions, and while they were engaged in a mighty war of words the water had to be waited for. In 1771 the system of obtaining water from a distance, and carrying it into Paris by aqueducts, found a principal supporter in the illustrious Lavoisier, who lent to this project all the weight of his genius.

At length appeared two able men, both merchants, who overcame those difficulties. The brothers Périer proposed to the city to establish, at their own expense, a system of machinery on the Seine consisting of a number of pumps, by the aid of which water could be raised. The citizens of Paris were about to see at work steam-engines which had been constructed in the workshop of Watt, they were to drink water elevated by the apparatus which was then exciting so just an admiration. Public opinion was not slow in testifying to the favour which the Périer system had found. On the 7th of February, 1777, the parliament authorised the brothers Périer by letters patent to establish at their expense, in localities indicated by the provost of the merchants, steam-engines which were to pour the waters of the Seine into the capital. The new company was organised forthwith, but it began its operations with a deplorable mistake. The first steam-pump was established at Chaillot, near the discharge of the drains. Delays, unlooked-for obstacles, unforeseen disappointments, put a stop for some time to the work, and the capital of the company was completely exhausted. Finally the advent of Law, the creation of his system, and the commencement of stock-jobbing, turned the heads of the money-making public, and caused the water speculation, like so many others, to collapse.

The company certainly gave water in 1782, but the promises it made were so badly kept, its engagements were so little respected, that government became compelled to interfere, and the undertaking was put a stop to altogether. A lawsuit, indeed, was carried on for some time on the subject. Beaumarchais defended the company, and Mirabeau opposed it. The author of "Mariage de Figaro" proved incapable of parrying the blows of the famous orator, and his accustomed genius deserted him. Truth appeared cold in the public eye, and the sonorous, clear, precise language of the Comte du Mirabeau crushed the Water Supply Company to atoms, and threw it into the most complete disrepute.

The eighteenth century produced, however, in this as in other respects, some progress. At the period when the French Revolution broke out, Paris received 10,445 cubic yards of water a day. The city then numbered 547,755 inhabitants, and the distribution was consequently three gallons per head in 24 hours. This volume of water would be only enough for one-seventh of the population, and consequently the progress in the eighteenth century is not of much interest; but an age which listened to Voltaire and Rousseau had but little time to bestow upon problems of this description.

During a long series of years, terrible political convulsions diverted the minds of men from questions purely administrative. The capital was taken out of the country, and financial speculations on the subject of Paris water were arrested. We must make a leap to the year 1797 before we come to any project so enterprising or so beneficent as that of the construction of the canal of Ourcq. After numerous debates and protracted discussions, and after having passed through the most unlooked-for phases, this project appeared likely to become actually carried out under the auspices of the first Napoleon. The Legislative Assembly passed a decree in which it was ordained that a canal of derivation should be opened from the river Ourcq, and that this river should be conveyed to Paris into a basin near La Villette. The first works were commenced in 1801, and on the 15th of September of the following year M. Girard took the direction of them. Carried on with activity till 1812, suspended by our internal disasters, and again recommenced at a much more recent period, these works were completed in 1837. After the completion of the canal of the Ourcq, after the establishment of eighteen steam-engines which draw water from the Seine, and the boring of the Artesian wells of Grenelle and Passy, the city of Paris received 255,000 cubic yards of water a day. This supply is contributed in the following proportions:—

	Cubic yards.
Water from the Ourcq	137,000
Water from the Seine	105,000
Water from the Artesian wells	13,000
Total	255,000

This gives a mean of 25 gallons to each inhabitant in 24 hours, a quantity inferior to that which is received by certain other great towns, as may be seen by the following table:—

P

	Gallons to each inhabitant each 24 hours.
Modern Rome	208
New York	125
Marseilles	41
Genoa	26
Glasgow	22
London	21
Geneva	16
Philadelphia	15
Edinburgh	11

Paris is, as will thus be seen, far from having a place in the foremost rank of towns well supplied with water. It is excelled in this respect by several; there is also room for improvement, not only in the *quantity* of our water, but in its *quality*.

The Water of Paris.

The following table gives an analysis of the chemical composition of the water which is drunk in Paris:—

	From the Seine at Chaillot.	From Arcueil.	From Belleville.	From Saint Gervais	From the Wells of Grenelle.	From the Canal of the Ourcq.
	gr.	gr.	gr.	gr.	gr.	gr.
Bi-carbonate of lime	0·230	0·158	0·400 (lime and magnesia)	0·032	0·029	0·158
Do. of magnesia	0·076	0·060		0·012	0·009	0·075
Do. of potash	,,	,,	,,	,,	0·010	,,
Sulphate of lime	0·040	0·138	1·100	0·430	,,	0·080
Do. of magnesia	0·030	0·072	0·520	0·100	0·032	0·095
Chloride of calcium, sodium, &c.	0·032	0·081	0·400	0·600	0·057	0·113
Silex, oxide of iron, alumina	0·024	0·018	0·100	0·020	0·112	0·109
Organic matter	Traces	,,	,,	,,	,,	,,
Salts contained in 1000 parts	0·432	0·527	2·520	1·194	0·149	0·590

From this analysis, drawn up by MM. Boutron and Boudet, we gather that the wells of Grenelle are preferable to any of the others. The waters of Belleville are hard and disagreeable to drink; while those of Arcueil are soft and of good quality.

The water from the Seine and the Ourcq, contaminated by impurities, have become unfit for human consumption. These rivers constitute the principal beverage of the inhabitants of our city. The Seine is the common drain into which the two millions of people who dwell upon its banks pour all their sewage. This water it is which the pumps of Chaillot and St. Ouen daily distribute to a large proportion of the inhabitants of Paris.

After the great drought of 1858, 58 cubic yards of water passed every second under the arches of the Pont Royal; and as the drains poured 1·3 cubic yards of water every second, it follows that the inhabitants drank at that period one pint of drain-water to each forty-four pints of Seine-water.

The water of the Seine stored in the reservoirs of Paris leaves much to be desired, as the observations of Dr. Bouchut and M. Coste have proved. The former tells us that the water of the reservoir Racine contains at a depth of 13 feet "myriads of yellowish particles, which give it the appearance of a thick emulsion." "The water of the reservoir of the Pantheon," says the same writer, "holds in suspension innumerable living creatures, which can be taken up by spoonfuls. In the Popincourt reservoir, also, the water of which is subject to the effects of light and heat, there is an immense quantity of impurity."

The water of the Seine, which is drunk by the inhabitants, is thus impure, filthy, and infected by the disgusting contents of the drains; it is full of organic matter of all sorts, and infusoriæ swarm in the reservoirs. Visitors to Paris frequently find themselves much affected by the water of the Seine, and some medical authorities consider that the use of this water is the cause of numerous diseases, especially fevers of a typhoid character, which often attack new-comers to the metropolis.

Besides this defect in quality, there is the deficiency in quantity, to which we before made allusion. During the summer the Bois de Boulogne and the Bois de Vincennes absorb 46,000 cubic yards of water a day. The water-posts sprinkle 118,000 cubic yards upon the high-roads; the squares consume 33,000, and the streets and boulevards require for watering 105,000 cubic yards. There remains to each person's share a few quarts of dirty unwholesome water; whereas, proper sanitary arrangements require 13 gallons of a pure and fresh liquid for each inhabitant of a large town.

Notwithstanding the immense quantity of water thrown on the public streets, the dust in Paris often rises in thick clouds; the lakes in the Bois de Boulogne by no means overflow with water; and the Parisian, wiping his forehead and melting under a burning sun, feels that he has no alternative but to quench his thirst from a species of decoction of the water of the sewer mingled with that of his river.

The Remedy.

Since the year 1864—the period when Paris first began to undergo the wonderful transformation which is now taking place, when stately boulevards were raised on the site of squalid hovels, and squares were distributed over the new capital—the municipal authorities found that they must deal with this problem of the water, and have resolved to attack with energy the evils so long existing.

But how are the evils we have been describing to be met To filter and to purify the water of the Seine would be impracticable, and this expensive mode of distribution would merely furnish the Parisians with a beverage of but doubtful quality. A thousand projects have been suggested. One set of projectors wished to have Artesian wells in every quarter of the city, but the water of an Artesian well is tepid and not aërated; and besides, does not every one know that the well of Passy has diminished the quantity of water in that of Grenelle? Would it be wise to dig twenty or thirty wells of the same description, and thereby diminish, and perhaps exhaust, the subterranean body of water which supplies the capital? Have we never heard of gushing fountains and springs which suddenly have become dry? Might it not some day be the same with these reservoirs which lie beneath our feet? Others proposed to bring the Loire into the middle of Paris, but why abandon one river to adopt another? Those dwelling on the banks of that stream, whose generous waters have been so immortalised by La Fontaine, would they not view with a very legitimate displeasure the removal of their river? It would not be any satisfaction to them to see the thirst of the Parisians quenched at their expense.

If we are to seek water from a distance, would it not be better to seek the purest, the freshest, and the most limpid which can be found? Many centuries ago the Romans understood the art of obtaining and distributing good water; they spared no pains in trying to obtain a fresh and wholesome beverage. At Rome itself they despised the Tiber, which flowed at their feet; the water of this river appeared unworthy to be drunk by the masters of the world, and they brought into the Eternal City the water of distant springs, by means of those gigantic aqueducts, the very ruins of which are sufficient for the supply of modern Rome. At Lyons they despised the Rhône and the Saône, and introduced the crystal waters of remote springs by long aqueducts. Lastly, here in Paris, the Emperor Julian, in his palace of the Thermæ, situated on the banks of the Seine, would only bathe in the waters of Arcueil.

Animals, who have not our intelligence, but who possess a marvellous instinct, invariably prefer spring water. If you offer a thirsty horse the choice between two pails of water, one containing water rich in sulphate of lime, and the other containing pure spring water, the animal will be certain to choose the second; and if no choice be allowed him, he will drink the first with manifest repugnance.

It has, therefore, been determined to imitate the Romans, and to spread over Paris spring water brought by one or more aqueducts. In April 1854 the prefect of the Seine commissioned Belgrand, chief engineer of the navigation of the Seine, to study minutely all the springs which could be made use of in increasing the water-supply of Paris, and which were situated at such an altitude that the incline of the ground could conduct them naturally to the hill of Belleville. The difficulties were great, but M. Belgrand's ability was sufficient to cope successfully with them. He thought with reason that all water coming from the same class of rocks would present the same composition, and that the substances held by it in solution must, when submitted to chemical analysis, give the same results. All the water, for instance, of the chalk soil of Champagne is sensibly of the same nature. The analysis of several well-selected springs could then represent the average composition of all the different waters to be met with throughout the whole extent of a formation.

M. Belgrand made consequently the analysis of 229 springs, measuring their temperature day by day, in winter as well as in summer, acquainting himself with the total amount of water given out by each, &c. He arrived at the conclusion that the water of Morvan was of excellent quality, but that its distance from Paris was too considerable; that the water of La Beauce presented the characteristics of a wholesome and pure beverage, but that its employment in large manufactories was so essential that we were not justified in diverting it for the use of the metropolis; finally, that the water of Champagne, situated between Châlons and Château Thierry and between Sens and Troyes, answered completely to all our requirements.

In the month of April, 1859, the city of Paris purchased, for the sum of about 65,000 francs, the source of the Dhuis, which flows near Château Thierry, and is capable of furnishing 52,000 cubic yards of water a day. The city afterwards purchased, for the sum of 12,000 francs, the springs of Montmort, in order to unite them to the waters of the Dhuis in the aqueduct, by which it was intended that the higher quarters of the city should be supplied. The other aqueduct, which was to be constructed for the use of the lower quarters, was to be fed from various springs in the valley of the Vanne, a little river which flows between Troyes and Sens, and which gives every day a volume of water equal to 88,000 cubic yards. In 1860 these springs were purchased for a sum of 265,000 francs. The city of Paris is, then, the proprietor of 157,000 cubic yards per diem, that is to say—

		Cubic Yards.
Water supplied by the Aqueduct of the Dhuis	Dhuis	39,000
	Springs of Montmort . .	4,000
Water supplied by the Aqueduct of the Vanne	Springs of Noé Theil, &c. .	88,000
	Springs of Armentières . .	26,000
		157,000

Besides these two aqueducts, which can thus furnish 14 gallons of spring water a day to each inhabitant of Paris, the Government proposes to erect a third, that of Somme-Soude, which would be able to bring into Paris a stream of 78,000 cubic yards a day.

At the point of departure of the Dhuis water an artificial waterfall is produced, by which the liquid, having fallen in drops, is freed from its excess of carbonate of lime; for a distance of 1,200 yards a double aqueduct has been erected, so that the circulation of the water may not be stopped when it is necessary to remove incrustations. The aqueduct extends over the hills which border the left side of the Marne as far as Chalifort, crosses that river, and keeps along its right bank as far as Belleville, after a journey of 87 miles. In order that the water may preserve its temperature, this aqueduct is formed of galleries of masonry united at the passage of the valleys by large cast-iron pipes, sunk one yard below the soil. Several months ago the work was so far completed as to bring the Dhuis to the hill of Menilmontant, at a height of 118 yards, and its waters are brought into Paris after having been collected in reservoirs, which contain not less than 22,000,000 gallons of water. These gigantic cisterns are covered in, and this envelope keeps the water at the temperature of the springs from which it proceeds, by protection from the solar rays, thus rendering the development of organic life to any injurious extent totally impossible.

One of these reservoirs being already completed, the other will soon, it is hoped, be successfully finished; and it is impossible to avoid admiring the beautiful azure hue of the water, and enjoying the touch of its fresh coolness when the hand is plunged in it. We fancy, while gazing into the liquid depths of the transparent waters of the reservoir, that we must be on the banks of one of the beautiful Swiss lakes.

It will not be long ere, not only the Vanne waterworks, but also those of Somme-Soude, shall have been completed. Paris will then have at her disposal 37 millions of gallons a day, which will correspond to 19 gallons of pure water to each inhabitant. Let us hope that householders will make such domestic arrangements as will enable their houses to be speedily supplied with this precious and invaluable benefit.

The Seine, the Ourcq, the Artesian wells, and the springs of Arcueil will then be used for the cleansing of the city; and our streets, our boulevards, our kennels, drains, &c., will be cleansed every day by a stream of water averaging 26 millions of gallons. When the undertaking is finally achieved, Paris will be supplied with 58 gallons to each inhabitant. This is, however, but small in comparison with the volume of pure water enjoyed by ancient Rome, and averaging 264 gallons each day to each inhabitant. Let us return our warm thanks to the country of Champagne, which, not only prodigal of the delicious wine of its hills, bestows on us also with a free hand the pure and fresh water of its springs.

In every country in which any attention is bestowed by the municipal authorities of the towns to sanitary arrangements much care is taken to ensure a good water-supply. Everywhere associations are formed for the purpose of obtaining an ample supply of the invaluable liquid. Thus, in America the inhabitants of Chicago have built an immense tunnel, sunk beneath the level of Lake Michigan, which furnishes them daily with a supply of water exceeding 44 millions of gallons. In London the most enterprising undertakings on the same subject are being brought under discussion.

The engraving (Fig. 52) represents the different modes of carrying water in different countries; it is probable that these types will soon die out, the best method of distributing water being the construction of an aqueduct, which by means of long pipes brings into all dwellings a pure and cool water, instead of a liquid polluted in a leather bottle or heated in a pail.

Drains.

To shed water profusely in the streets of a town, to distribute abundantly the liquid element among its numerous inhabitants, to water frequently its squares and public walks, all this constitutes the first part of the problem which we have been examining. But in the town as in the fields, drainage must follow irrigation, if we do not wish the city to become unwholesome. When once the water has fulfilled its purifying mission, when it has swept the gutters, given drink to the citizens, and brightened up the gardens, it has become corrupt, it has deteriorated and grown turbid, it becomes charged with putrid matter, and has to be removed from the city.

Paris had formerly but three drains—the Seine, which went through Paris, and the natural drains, situated each on one bank of the river; the Bièvre, and the brook of Menilmontant, which, after having followed the course of the external boulevards, joined the Seine at Chaillot. The first covered drain dates from 1343. At a later period, Francis I., being desirous of removing a drain from the vicinity of his palace at Tournelles, proposed to remove nearer to the markets the polluted stream, the offensive odour of which had mounted to the royal nostrils. But the provost of the merchants stoutly resisted the will of his majesty, and absolutely refused to infect the markets and the Rue St. Denis. Francis was obliged to change his residence, and erected the palace of the Tuileries.

In 1610, Marie de Medicis, feeling anxious lest the health of her subjects should suffer through the maladies which threatened to result from the stagnant water and other nuisances which accumulated in the drains, charged the treasurer of France to see to their clearing. But notwithstanding the directions of the queen, no cleansing of the drains was made, save that which heaven accomplished by means of rain. Water was literally wanting for drink, and the evil grew greater and greater each day.

Towards the middle of the eighteenth century Turgot caused the sewer of Menilmontant, which gave out the most disagreeable and unwholesome exhalations, to be cleared out. At the commencement of the present century the sewers were cleared out, but the absence of water was long an obstacle to this process.

In fact it was not so long ago that the subterranean arrangements of Paris were still a real source of danger to the public health, of which fact we need no stronger confirmation than will be afforded us by the perusal of a work published in 1824, by Parent-Duchatelet, on the subject, stating the inconveniences resulting from the then existing system. Parent-Duchatelet distinguishes in the drains six different species of emanation prejudicial to health. The least disagreeable one, which is peculiar to the better sort of drains, is a faint odour, which, though not so disgusting as some of the others, yet enervates and produces sickness. The next specifies an *ammoniacal odour*, which produces ophthalmia; then a still more dangerous escape of *sulphuretted hydrogen*, which strikes those venturing too near with a species of asphyxia. We need not enter into particulars respecting the other three. We may leave the reader's imagination to picture the injury which *cloacæ* shedding these abominable odours through the town must have done to health. In the year 1830 we find a decided improvement in the sewerage of Paris, resulting from the cleaning out of the drains effected by the canal of Ourcq. But this incontestable progress was accompanied by an evil which still exists. The impure streams which traversed the Parisian soil discharged themselves in the centre of the town into the Seine itself, in black torrents, which every one walking on the quays must have remarked polluting the shores of our river and poisoning the air in the neighbourhood.

This odious and uncivilised system is about to disappear. The drains will in future discharge their contents into a large reservoir, which will carry the drainage-water of Paris down stream below the bridge of Asnières, after having traversed Clichy in a tunnel.

This work will be the most remarkable and the greatest of any of the same kind which have been undertaken by any nation. The *cloaca maxima* of ancient Rome, which has hitherto been considered with reason the masterpiece of sewerage works, is smaller in its dimensions. The form of the Asnières drain is oval.

In a few years' time the numerous ramifications of the subterranean hydraulic system of Paris will all be constructed on the model of the drain which forms a vast tunnel under the macadamised road of the Boulevard de Sebastopol. During the whole course of this subterranean artery the odour is so slight that one is able to perceive the smell which emanates from the neighbouring perfumery establishments. An interesting journey can be made through this subterranean way, either in a boat or by train, and the sense of smell is not subjected to too severe trials. Underneath every house a sink will be in communication with the drain, and the cleansing of cesspools will be managed underground, by means of wagons which will glide rapidly over iron rails. These subterraneous conduits will also receive the telegraph wires, the water-pipes, and perhaps those for the gas of Paris.

In 1853 Paris and the suburbs had 119 miles of drains, which, placed end to end along the Lyons railway, would have reached the town of Tonnerre. In a few years they will form an immense canal, which, drawn out in a straight line in the direction of Berlin, would enable the Parisians, were they so minded, to invade the Prussian capital underground.

Notwithstanding all these improvements, there are some subjects for regret in this vast network of subterranean highways. The impure waters which circulate therein do not, it is true, any longer flow into the Seine in the middle of Paris, but they poison the river below Asnières, to the very natural annoyance of those who live on its banks. In the second place, the drainage waters of the capital, disagreeable and injurious as they are to man, are highly beneficial to the vegetable world; they are a source of nourishment, nay, of life, for cereals, vegetables, fruit, and all the productions of the earth. A mine of gold is thus thrown into the sea, and is consequently a dead loss to the country from which it comes.

Let us hope that our descendants, carrying to perfection those works which their forefathers commenced, will be able to draw profit from this source of wealth, so neglected by ourselves; that they will give to the soil the liquid distilled in the veins of our great cities, and pay those cities back by the cultivation of a new source of prosperity.

Yet let not these imperfections lead us to exaggerated complaints; let us look back to the past, and recal the Paris of the middle ages, in which the burghers had only one litre of unwholesome water per diem. Let us think of our ancestors, who, always incommoded by exhalations the most fatal to health, had, whenever they walked through the streets, to cross streams of dirty water. Pure water, shed over our towns, after having fulfilled its useful work, will one day answer all the requirements of agriculture; the sewage extracted from inhabited spots by the great system of drainage now being carried on, will be transformed into wheat and barley. The circle will be complete. The drop of water carried by the hand of man, will have a mission similar to that of the other drop which the hand of Nature has snatched from the sea, in order to shed it upon the continents which it is destined to fertilise.

CHAPTER VIII.

ARTESIAN WELLS.

Subterranean Reservoirs.

IT is not merely from the beds of rivers that man can draw the liquid which is so indispensable to his existence. The earth on which our cities stand conceals subterranean aquatic treasures which are ample enough to water entire countries and to quench the thirst of the most densely populated towns; but these vast reservoirs are defended by rocky strata, which seem to play the part of the dragons of ancient fable. What unwearying labour is required to enable us to possess ourselves of these treasures which Nature seems to hide from our view!

It is interesting to read of Arago, who, after waiting with unexampled perseverance, at length beheld water bubbling up in the wells of Grenelle, bearing witness to his genius and to the justice of his predictions.

The great masses of water which lie upon the surface of the globe are situated at different elevations above the surface of the sea. The waters of some lakes, such as those of Lake Panin in Auvergne, and of Oeschi in Switerland, are at great elevations, in natural reservoirs hollowed out of mountains.

We can suppose that water from a height penetrates by subterranean channels into the earth, and thus extends to a great distance from the point whence it started. If the soil be pierced *above* these subterranean waters, the liquid, obedient to the laws of hydrostatics, will rise in the hole thus thrown open to it, until it reaches the level of the original reservoir whence it escaped. If, however, the level of the reservoir be above that of the soil in which the Artesian fountain has been bored, the water gushes up like an immense *jet d'eau.*

Artificial water-works are, in fact, merely varieties of Artesian wells. Those of the Tuileries, for instance, draw their water from the hills of Chaillot, and rise to a considerable height, merely from following the natural law by which water seeks its own level. We can illustrate these principles by a tube in the shape of the letter *U.* If water be poured into one branch, it will rise in the other until the levels of the water in the two tubes is the same.

This simple principle has always been regarded as applicable to Artesian wells. In 1671, Cassini said, speaking of the fountains of Modena, "Possibly these waters have travelled by subterranean channels from the heights of the Apennines, a distance of ten miles."

All water situated in the soil will not, however, rise to the surface. There are certain *waters* generally to be found at a slight depth, which furnish merely an impure fluid, often adulterated with the fetid infiltrations of cities. Those boring an Artesian well must penetrate farther. They must force their way into the soil, and they will be rewarded by ultimately overcoming all obstacles and finding a copious supply of pure water.

The prophets of Brahma understood the art of digging wells; and in China there is an artificial excavation, of which the origin is extremely ancient, and which was originally destined for the purpose of finding rock salt. This well has a depth of 638 yards. The Chinese, our predecessors in so many valuable and useful discoveries, have long understood the art of boring Artesian wells.

Artesian wells were introduced into France in the year 1126. The first was executed in Artois, and the name of that province has been bestowed on these fountains. In the 17th century Cassini caused an Artesian well to be constructed at fort Urbain, capable of throwing up water to the height of sixteen feet above the level of the ground. Bernard de Palissy, who may be looked upon as the father of geology, since he was the first to recognise that fossils are vestiges of former organised beings, had also conceived the idea of the Artesian well.

After the well of Artois, and that of Cassini, other wells were dug in various localities, in which the water was not far below the soil. The most remarkable fountains which have been obtained in France have been at Tours, at Saint-Ouen, at Elbeuf, and at Perpignan. England and Germany have also raised the precious liquid from the bowels of the earth by Artesian wells.

The Well of Grenelle.

Five years subsequently to the Revolution of July, Arago having proved that the subsoil of Paris was adapted to collect the subterranean water which extended over the neighbouring country, and that Nature herself seemed thus to have adopted the system of centralisation with regard to waters which travel through the interior of the earth, induced the municipal council to provide for the wants of the metropolis by having certain wells sunk. Arago and others affirmed that subterranean water existed beneath the level of our capital. But at what depth was the water to be found?

The result of the investigations showed that these subterranean reservoirs were protected by a formidable stratum, of which the dimensions were worthy of one of the principal capitals in the civilised world.

Arago proposed to pierce the deposit formed by the cretaceous ocean, and to reach the green sands, the outcrop of which appeared on the surface in the neighbourhood of Troyes. The council of ministers appeared hesitating and perplexed, but Arago guaranteed the success of his undertaking, and in due time received authority to carry out his scheme.

On the 29th of November, 1833, the implements which were to carry out one of the greatest boring works which have ever perhaps been executed, were carried to Grenelle. The machine was at first worked by several men; but men were soon replaced by horses, and the direction of the works was confided to M. Mulot, who displayed, through the whole of the undertaking, the most indomitable perseverance. What mortifications, what cruel disappointments had he not to endure! But he had faith in the ultimate success of his scheme, and was certain of ultimately bringing it to a happy issue.

The first portion of the work was completed without obstacle; but in undertakings of that description it must be borne in mind that the difficulties augment in proportion as the work advances. Many times during the progress of this work, which was commenced in 1833, the borer broke and became lost in the well. What a perplexity to the engineer, who has not only lost his tool, but finds the road which he ought to open into the ground, blocked up with an enormous mass of steel! How is he ever to remove from a dark hole, full of mud, full of water, fragments of iron firmly fixed in the stone?

Arago himself relates the thousand hindrances which he found in his work, and the varied emotions to which it gave occasion. On the 30th of November, 1834, the borer broke into seven pieces, and could only be got away three months later. Again, four years after the commencement of the work, in 1837, the tool fell for the third time by a cable breaking. The work was thus delayed for a space of fourteen months. Nothing as yet announced that the well was approaching completion. The funds became exhausted, and still the water was not reached. It appeared, indeed, as if these deplorable accidents would be certain to put an end to the whole undertaking.

But Arago, fertile in resources, and possessed of a persuasive eloquence, succeeded in reviving the confidence of those on whose aid he depended for the carrying on of his work, and in spite of new difficulties constantly arising, the work went on. Daily they came nearer and nearer to the liquid so much desired.

At length this admirable enterprise reached the wished-for termination.

They had reached a depth of five hundred and ninety-six yards, when on the 25th February, 1841, the borer brought up the green sand, very wet and clayey, which greatly revived their hopes. Consequently, at an early hour the next morning, masters and men were already at their posts.

The following day the borer went down easily to a length of 1·6 feet. It was a good sign. Suddenly the horses which were being used in the works experienced a violent shock, which broke the machinery, and the director of the works cried out, "*The borer is broken, or we have the water!*" Presently a gushing sound was heard, and the water rushed up with force.

Some hours later, Arago, who was then present at a sitting of the Chamber, received the following note :—

"Monsieur Arago,

"We have the water. "MULOT."

This occurred on the 26th of February, 1841, at thirty-two minutes past two.

The work was commenced on the 29th of November, 1833.

The Well of Passy.

The works which had been executed at Grenelle only cost the city of Paris £14,000, and the sale of the waters of the new well to public establishments and private individuals soon covered the expenses of the enterprise. The municipal council, when they listened to the advice of Arago, had made an excellent monetary speculation. It was thought that new Artesian fountains would give the supply of water of which Paris stood in need, but it was not so.

In 1850, the city of Paris conceived the idea of transforming the Bois de Boulogne into an English garden, and required, necessarily, a large supply of water to fill the intended lakes, feed the artificial rivers, imitate the falls of the Rhine, and improve to the utmost the walks which were to be the delight of the citizens.

A German engineer, M. Kind, announced that he would undertake to make a fountain, by constructing an Artesian well upwards of a yard in diameter, which should furnish 17,000 cubic yards daily.

A commission was appointed to examine into this offer and the feasibility of accepting it; the commission finally determined that the offer should be accepted. It would have probably been considered as too great an expenditure of money, had it been a plan for supplying the wants of the needy, or a project for setting on foot some exclusively useful work; but superfluities were supposed to be indispensable to the well-being of Paris, and the requirements of luxury have often provoked efforts more energetic, more laborious, and more self-denying, than those connected with health or public utility.

The administration, impatient to terminate the works which had been commenced at the Bois de Boulogne, exacted of the engineer the promise that they should be finished in a year's time. M. Kind accordingly engaged to complete the Artesian well of Passy in twelve months, promising also that the expenditure incurred should not exceed £14,000. But he doubtless had forgotten at the time that the best-laid plans are frequently overthrown by unlooked-for contingencies, for, as it proved, the well of Passy cost four times more money, and took four times longer time for its completion, than had been anticipated at the beginning. But if we take into consideration the difficulties which had to be met, we can only congratulate ourselves on having obtained so successful a result even at that price.

The well of Grenelle was dug by means of a drill with steel teeth, which, being raised and let fall, by its weight broke the rock which it was penetrating. The improvement made by M. Kind consisted in such modifications of the drill and boring rod as prevented the terrible shocks which formed one of the greatest difficulties in digging the well of Grenelle. When once the rock is sufficiently broken by the drill, that implement is withdrawn from the hole, and replaced by a tool which carries away the débris of the rocks and the pulverised matter. This tool is a cylinder, fitted at its lower part by a valve which opens from the exterior to the interior. When this cylinder is forced down, the valve opens, permitting the sand and fragments of rock to penetrate into it. When it is raised the valve closes, and so imprisons the materials, which can thus be drawn away from the well.

As the drill goes deeper into the earth, it is necessary to line the well with an iron tube, which is intended to form a water-tight channel by closing any apertures through which the water might escape when on its way to the surface. The operation of tubing is very dangerous, and proved, during the digging of the well of Passy, the cause of numerous accidents, which nearly compromised the success of this great enterprise. After protracted efforts and assiduous toil, the engineers attained the depth of the well of Grenelle, and the water came rushing violently up to the surface of the ground. As soon as this new supply issued from the bosom of the earth, the quantity of water furnished by the well of Grenelle diminished sensibly.

The well of Passy, though deep, is less so than some other wells, which reach from 650 to 700 yards. The wells of New-Salzwerck and Mondorff, for instance, go into the earth to a depth of 400 and 798 yards. The water of the well of Passy is lukewarm, and indeed in every respect resembles that of Grenelle. It becomes fit for the table as soon as it has dissolved the gases of the air and reached a temperature sufficiently low.

Utilisation of the Central Heat of the Globe by means of Artesian Wells.

For many centuries successive generations of travellers have traversed the earth from one end to another, and given us descriptions of lands hitherto unknown. So great is the extent of these explorations that the time is approaching when we shall have made known to us the whole superficial extent of the globe. But it is otherwise with subterranean geography. What mysteries are concealed beneath the earth's surface! The depths of the earth are as little understood as the depths of the firmament, and we are little more acquainted with the constitution of our own planet than with that of the most remote star; and yet how deeply interesting, as well as useful, are subterranean explorations, and what result could be more advantageous than to utilise the central heat of our planet!

Volcanoes, hot springs, and Artesian wells, all prove that an excessive heat reigns at a certain depth. Enormous expenses are incurred in bringing to the surface of the earth the coal necessary to supply us with heat; but would it not be possible to bring the heat itself, instead of the combustibles which produce it? Is there anything impracticable in the idea of sending into the bowels of the earth water which should come back boiling to the surface of the soil, and supply us with the steam necessary for our machinery? All things may be accomplished by means of heat. Human labour is replaced by the labour which is produced by the combination of a few pounds of coal. By means of fire, the inclemencies of the seasons and the inconveniences of intemperate climates may be warded off, alimentary substances may be modified, the development of plants aided, bodies decomposed, and the number of vegetable productions possible in any given climate infinitely extended.

What we have to do, therefore, is to snatch from the jealous grasp of earth that precious element which it possesses in such great abundance, and to remember that Prometheus, when he bestowed fire on man, gave him the empire of the world. The earth is a vast mine of heat, which ought not to be left unworked. We are not here speaking of the well of Maupertuis, that famous well of which Voltaire writes, which ought to cross the globe from one side to the other, in order that we might have the pleasure, when standing upon its edge, of seeing our antipodes. Here we have only to pierce to a depth of a few miles at most, and then we shall have attained the temperature of boiling water. Elie de Beaumont, Walferdin, and Babinet have more than once succeeded in drawing public attention to this great question, without, nevertheless, obtaining any results. Will this vast enterprise ever be realised? That is a question we cannot answer; we can but hope that one day some second Arago will accomplish this task, gigantic if we compare it with a man's stature, but small indeed relatively to the diameter of our terrestial sphere. A great number of geologists, and other men of science, have already thrown out the idea which we are here reproducing; but the day is probably still a distant one which will enable us to make of the earth itself an inexhaustible mine of boiling water and of motive force.

CHAPTER IX.

THE OASIS IN THE DESERT.

IF the countries through which roll rivers and cool water courses offer to us the gladdening spectacle of abundant vegetation and natural luxuriance, arid and dry countries present nothing to our sight but endless wastes of sand, entirely devoid of verdure, and forming a picture of wildness and desolation.

But if in the midst of these burning deserts, dried up as they are by the rays of the sun, water comes bursting from the earth, the sands will no longer be sterile, but impart life to plants, which rapidly grow up beneath the influence of a beneficent moisture, and the desert will speedily be covered with verdure which, spreading its dimensions daily further and further, will form the subsistence of the animals which make it their abode. To Nature dying, barren, and desolate, will succeed Nature rich, living, animated, gay with the charms of a generous vegetation.

The vast desert of Sahara has not always been a plain of sand, and the numerous sea shells which are to be met with there, teach plainly that the site of the Sahara was once covered by the sea. On some of its hills we can even discern traces of the action of the waves, and the sand is usually impregnated with salt. Here and there, indeed, salt lakes occur, like the last drops which adhere to the bottom of a vase that has been emptied.

It is probable that the ocean, which formerly covered the desert, dried up slowly, and has gradually risen from it in the form of vapour. Rain is very rare in these burning zones; the mountains which are to be found there are but seldom crowned with a diadem of snow, and Heaven refuses to these regions the water of which she is so prodigal in other countries. The water evaporated by the sun has never been replaced, and in time an inland sea has been dried up. A sea of sand has replaced the liquid ocean, and the eye of the traveller who traverses these deserts penetrates to a remote horizon without perceiving anything save an infinitely prolonged plain, a vast sheet of a yellowish hue, without visible limit.

But beneath the sand of this desert lies a liquid layer, which man can utilise, and for many years modes of digging wells have been known to the native tribes who inhabit the borders of Sahara. Tools of the rudest character are employed. Armed with the most indomitable patience, they slowly dig into the earth; little by little they make their way into the ground, scraping away and throwing upon the edge of the hole they have made the earth as they dig it out. After having successively pierced the layers of sand, gravel, and clay, they attain a hard crust not unlike slate. This envelope covers the precious liquid, the Bahr-el-Tahani (*sea below the earth*); to penetrate this crust is the last effort of these indefatigable workers, for the water then bursts forth with great ascensional force.

If the diggers frequently risk their lives, they have the consolation of finding themselves the objects of absolute veneration by their compatriots; they form a corporation, known under the name of "Ghattas," and the severest labour is for them the noblest ambition. They are deterred by no obstacle; and the well which is dug in ground perfectly dry is frequently finished under a depth of water many yards in thickness, due to the waters of infiltration which it is impossible to avoid.

Picture these unhappy natives, compelled to plunge in the liquid and remain in it a few moments at a time, labouring in the muddy water, and bringing up again the few handfuls of sand which they have extracted, hoisting themselves up by means of a rope.

When their task is thus difficult, they are unable to accomplish in one day more than two or three subterranean journeys, hence it arises that the work proceeds with a slowness in the highest degree discouraging. The labours of several years are not sufficient to enable them to reach the wished-for goal, that of snatching from the sand of the desert the water with which it seems loth to part.

"Sometimes," says M. Ch. Laurent, "it happens that a plunger is suffocated, either before he reaches the bottom, or during his work, or whilst he is reascending to the light of day. One of his companions, who holds the cord which serves at the same time for direction and for signal, being warned by certain pulls that his fellow-labourer is in danger, hurries to his succour, whilst another replaces him at his post of observation, which he in turn has to quit, at a new signal calling him to the help of his two comrades."

Different indeed is this rude and elementary industry from the scientific method of digging wells possessed in our country; different indeed these handfuls of sand, extracted with so much difficulty, from the masses of rock which are broken through by our formidable drills, and to remove the fragments of which an immense iron ladle is employed. Nothing can resist our powerful implements, whereas a somewhat heavy layer of stone is to the native engineers an insurmountable barrier.

The well once dug, several beams of wood are placed along its sides to prevent their falling in; notwithstanding which precaution, these wells are not long-lived. In a short time the moist soil sinks in, and the spring so hailed and blessed is dried up for ever. Near the fountain the husbandman has been able to live, finding there the subsistence needful for his existence, a few palm-trees having protected with their foliage the first growths of the desert. But the well is choked; the oasis is destroyed. The burning wind from the desert destroys these vestiges of human industry—verdure and cultivation speedily disappear.

Two French engineers, M.M. Fournel and Dubocq, were the first who substituted our methods of boring for the simple and primitive proceedings of the Arabs. General Desvaux gave them a cordial and powerful support. "Chance," says this officer, in a report addressed to the Governor of Algeria, "led me to the summit of a sand-hill which overlooks the entire oasis. It would be totally impossible for me to describe to you the impression which the sight of this oasis gave me. On my right were verdant palm-trees, cultivated gardens, in a word—life; while on my left were sterility, desolation, death. I sent for the Scheik and the inhabitants, and was informed by them that the reason of this difference consisted in the northern well being choked up by the sand. In a few days the whole population would have dispersed, forsaking their hearths and the graveyards where their fathers slept. I saw in a moment, on hearing this, what valuable results would accrue to this country from Artesian wells, and thanks to you, who have so kindly received and encouraged my suggestions, life will be restored to many of the oases, and the future is pregnant with hopes of a most cheering character."

In 1855 M. Ch. Laurent took the command of an exploring party for the purpose of reporting on Artesian wells, and it was not long ere an expedition for boring was equipped, and M. Jus, a civil engineer, took the direction of the works for the well at Philippeville. The implements which this work necessitated were, under great difficulties, transported to the Oasis of Tamerna; but at length everything was in order, and, on the 1st of May, the boring was commenced upon the soil of Sahara. Five weeks later they had reached a depth of sixty-six yards, when suddenly a terrible noise was heard, and an immense torrent burst forth from the bowels of the earth, a torrent so abundant as to furnish 880 gallons per second.

The workmen thus received an ample recompence for their labours, which, for more than a month, had never been suspended, in spite of the rays of a sun when the thermometer indicated 46° in the shade.

The inhabitants of Tamerna and its neighbourhood were immediately informed of the good news, and rushed in a body to the spot. Every one wished to be present at the miracle, and to see with his or her own eyes this water which the French had been able to obtain in five weeks, while the natives had required an equal number of years and five times as many labourers. Women and children of all ages rushed towards the bubbling spring, and drank of it out of the cans of our soldiers. With frantic delight they embraced one another, and cries of joy disturbed the silence of these sandy plains.

This first well set a good example, and in a short time five others were sunk in the *desert.* The Sahara became enriched with a quantity of water equivalent to the current of a small river.

At Badna, at Biskara, at Ourlana, fresh Artesian fountains were dug; and at the present time the eastern Sahara is fertilised by bubbling springs, which pour upon the arid soil 130,000 cubic yards of water every twenty-four hours!

Henceforward man and civilisation will be enabled to invade these immense sandy plains, these vast deserts which arrest the development of life in certain parts of continents; and the human family will extend itself, thanks to Artesian wells, into regions which have been hitherto held accursed, but which can now be transformed into a vast oasis.

During the last ten years 150,000 palm trees have sprung up on the soil of Sahara, rendered fertile by the digging of Artesian wells; and these generous trees, by the shade they impart, daily improve the soil by sheltering it from the piercing rays of the burning sun.

Day by day the branches grow larger and spread further; and in proportion as they do so, cultivation of the ground beneath their shadow becomes easier. Certain parts of Algeria, which formerly suffered from the effects of the simoom, and the silicious soil of which was covered with a monotonous mantle of arid sand, are now hidden under a soft envelope of fertile earth, on which apricot trees grow, and from which, even in winter, crops of barley and other grains can be raised.

Too much praise cannot be bestowed on these noble undertakings, which have been crowned with such encouraging success; and the sinking these wells in the desert may be considered as one of the most lasting and glorious results of our invasion of Algeria, for this victory is entirely pacific, a hundred times preferable to those which are won at the price of blood. May these works inaugurate a new era, in which the reign of the sword shall give place to those battles which are waged by industry and agriculture!

We might prolong indefinitely our enumeration of the services rendered by water to man, to science, and to industry; and we should never have finished if we had to speak in detail of the multifarious uses to which the precious liquid lends itself. Steam, the great motive power, animates those engines of which every branch of industry makes so great a use; it is steam which carries the locomotive along the iron rail; it is steam which carries through the sea those enormous vessels, of which the paddles beat the waves like the fins of some formidable marine monster. Thanks to steam, industrious England has multiplied her forces tenfold. We find, from recent calculations, that the work she accomplishes annually by the aid of steam is equivalent to that which would be produced by 400 million men! As a liquid, water turns the mill-wheel and grinds our corn. Rivers and canals also assist in effecting communication between provinces and countries. These "moving highways" form the basis of commerce and of the intercourse between nation and nation. M. de Lesseps, in cutting the canal across the Isthmus of Suez, opens to Europe the high-road to India, and thus uniting two seas, the mingling of whose waters will give to civilisation a new impulse, he may be considered a worthy representative of modern science.

But all these questions, interesting as they are, must be passed over in silence, that our picture may not exceed the prescribed limits of its frame. Our little book is not, properly speaking, a scientific work, and we have only endeavoured to explain a few important facts in the history of one of the most potent bodies in Nature; we have simply sketched the part which it plays in the harmony of the world, the importance of studying it, and the advantage of its employment in industry and hygiene.

Jean Jacques Rousseau pretended that he considered science to have the effect of rendering men guilty and miserable, and avowed his preference for the ignorant man who led a peaceful life unconcerned about what surrounded him, over the scientific man who interrogated Nature. He forgot that it was not in man's own power to resist the noble aspirations which stir within him, the desire of knowledge which urges him on, the insatiable craving which will not suffer him to be at rest.

An ignorant man can, indeed, enjoy the physical pleasures of material life, but it is forbidden to him to enjoy the unbounded felicity which Nature reserves for him who comprehends her secrets, and to taste the ineffable joy of the seeker who succeeds in inscribing some lines, however few, in the vast volume of human knowledge.

THE END.

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